UNIVERSIDADE DE LISBOA

Faculdade de Medicina Veterinária

EFFECT OF PARITY AND SUTURE TYPE ON THE REPRODUCTIVE PERFORMANCE OF BEEF COWS SUBMITTED TO CAESAREAN SECTION

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LISBOA

À minha avó Ni

To my grandmother Ni

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Resumo

O efeito do número de partos e diferentes fios de sutura no desempenho reprodutivo de vacas de carne submetidas a cesariana

Na produção de bovinos, um bom desempenho reprodutivo é essencial para a eficiência da exploração. No caso das vacadas de carne, o vitelo é o principal produto. Assim, a máxima eficiência reprodutiva é fundamental para a rentabilidade da exploração.

Num elevado número de explorações de bovinos a reprodução não segue um plano ideal, limitando a sua própria economia. Assim, o objetivo deste trabalho foi compreender a influência da cesariana no desempenho reprodutivo das vacadas, avaliando o intervalo entre partos, o tempo de cobrição e a taxa de refugo em diferentes idades da fêmea e utilizando fios de sutura distintos.

Após a análise retrospectiva de 119 cesarianas realizadas numa única exploração, concluiu-se que o número de cesarianas e a utilização de Monodox® ou Monosyn® para a sutura uterina e Surgicryl® ou Safil® para suturar o peritoneu, músculos e pele, não apresentaram uma influência significativa ($p > 0.05$) no intervalo entre partos, tempo de cobrição e taxa de refugo. No entanto, deve ser enfatizado que a continuação da recolha de dados permitiria não só a obtenção de resultados mais próximos da realidade, como uma melhor avaliação das variáveis. Adicionalmente, o estudo de outros fatores seria benéfico, já que os parâmetros agora estudados, apenas explicam uma pequena parte da variação encontrada.

Palavras-chave: bovinos de carne; desempenho reprodutivo; distócia; cesariana; número de partos; fio de sutura.

Abstract

Effect of parity and suture type on the reproductive performance of beef cows submitted to caesarean section

In cattle production a good reproductive performance is essential to the herd's efficiency. In beef herds, the calf is the major product and so maximum reproductive efficiency is paramount in determining the herd's profitability.

In a large number of cattle farms, reproduction is not optimal, which may have an important negative effect on the herd's economy. Therefore, the main goal of this work is to understand the influence of the caesarean section in the reproductive performance, specifically in the calving interval, breeding interval and culling rate, at different dam's ages and using different suture materials.

After the retrospective analysis of 119 caesarean sections realized in a single farm, it was concluded that the number of caesarean sections and the use of Monodox® or Monosyn® for the uterus and Surgicryl® or Safil® for the peritoneum, muscles and skin, do not have a significant influence ($p > 0.05$) on the calving interval, breeding interval and culling rate. However, it should be emphasized that more data is needed to obtain results closer to reality and to allow for a better variables' evaluation. Furthermore, the study of other factors would be beneficial, since the parameters studied only explain a small part of the variation found.

Key words: beef cattle; reproductive performance; dystocia; caesarean section; parity; suture materials.

Index

I. Training activities' report ... 1
1. Training activities' in the Bovine Erasmus in Belgium ... 2
2. Training activities' at Vettotal - Serviços Veterinários, Lda. ... 5
II. Introduction ... 7
III. Literature review ... 8
1. Breeding goals in beef cattle ... 8
2. Reproductive Health Programs for Beef Herds: the measurement of reproductive efficiency ... 9
2.1. The age at first calving ... 10
2.2. The calving interval and calving index ... 12
2.3. The calving to conception interval and days open ... 12
2.3.1. The postpartum period in beef cattle ... 13
2.3.2. Major factors affecting the postpartum in beef cattle: the calf and the body condition ... 17
2.4. The percentage of cows cycling during the first 21 days of the breeding season ... 19
2.5. The first service conception rate and percentage of pregnant cows ... 20
2.5.1. Fertilization failure and embryonic losses ... 20
2.5.2. First service conception rate and percentage of pregnant cows: breeding goals ... 22
2.6. The productive life and culling rate ... 23
2.7. Calf analysis ... 25
2.7.1. Calf mortality ... 25
2.7.2. The percent calf crop weaned ... 26
3. General considerations about dystocia ... 27
3.1. Causes, incidence and consequences ... 27
3.2. The treatment of a dystocia case ... 32
3.2.1. The mutation of abnormal presentation, position and posture ... 35
3.2.2. Delivery by extraction ... 36
3.2.3. The caesarean section ... 40
3.2.3. The fetotomy ... 45
4. The dystocia as a cause of decreased reproductive performance ... 46
IV. The influence of the caesarean section in the reproductive performance of Belgian Blue Cattle ... 51
1. Introduction ... 51
2. Materials and methods ... 52
2.1. Data ... 52
2.1.1. The Institute for Agricultural and Fisheries Research (ILVO), Department Animal ... 52
2.1.2. Sample characterization ... 56
2.2. Methods ... 57
2.2.1. Measures of reproductive performance ... 57
2.2.2. Statistical analysis ... 58
2.3. Results ... 59
2.3.1. Calving interval ... 59
2.3.2. Breeding interval ... 63
2.3.3. Culling rate ... 66
3. Discussion ... 69
3.1. Calving interval ... 69
3.2. Breeding interval ... 71
3.3. Culling rate ... 75

IV. Conclusion ... 77
V. Bibliography ... 78

Figures index

Figure 1: The causes of dystocia (Noakes et al., 2009) ... 29
Figure 2: The foetal eutocic disposition (Meijer, 2005) ... 33
Figure 3: Flow pattern for parturition (Schuijt & Ball, 1980) ... 34
Figure 4: Anterior view of the pelvis of the cow: the 5 diameters from the anterior view (adapted from Hanzen, 2009). ... 36
Figure 5: Complications of the caesarean section (Kolkman, 2010) ... 40
Figure 6: Location of the Institute for Agricultural and Fisheries Research, Department Animal ... 53
Figure 7: Grass growth rate in Belgium (Hubrecht & Willems, 2010) ... 53

Graphics index

Graphic 1: Cases distribution in the Bovine Erasmus in Belgium ... 1
Graphic 2: Cases distribution in Vettotal - Serviços Veterinários, Lda. ... 2
Graphic 3: Evolution of the annual temperature in Belgium (Uccle station, 1981-2010) [adapted from Institut Royal Météorologique (n.d.)] ... 54
Graphic 4: Medium annual precipitation in Belgium (Uccle station, 1981-2010) [adapted from Institut Royal Météorologique (n.d.)] ... 54
Graphic 5: Calving distribution in the double-muscled Belgian Blue cattle at ILVO (1989-2013) ... 55
Graphic 6: The calving interval distribution (n=86, DM-BB, ILVO) ... 59
Graphic 7: The mean calving interval by number of caesarean sections and suture group (n=86, DM-BB, ILVO) ... 60
Graphic 8: The mean calving interval per caesarean section group (n=86, DM-BB, ILVO) ... 61
Graphic 9: Breeding interval distribution (n=85, DM-BB, ILVO) ... 63
Graphic 10: The breeding interval distribution after the first calving (n=44, DM-BB, ILVO) 64
Graphic 11: The cows breeding interval distribution (n=41, DM-BB, ILVO) ... 64
Graphic 12: The mean breeding interval by number of caesarean sections and group of suture (n=85, DM-BB, ILVO) ... 65
Graphic 13: Culling rate analysis per number of caesarean sections and suture group (n=33, DM-BB, ILVO) ... 67
Graphic 14: Culling rate analysis per number of caesarean section (n=33, DM-BB, ILVO) ... 68

Tables index

Table 1: The replacement heifer breeding efficiency (Morrow, 1980; Rice, 1986) ... 10
Table 2: The adult cow breeding efficiency (Morrow, 1980; Rice, 1986) ... 10
Table 3: Calf survival (Rice, 1986) ... 10
Table 4: The culling rate (Morrow, 1980) ... 10
Table 5: Influence of dam, sire and calf factors potentially associated with dystocia (Adapted from McDermott et al., 1992) ... 30
Table 6 The dystocia as a cause of reproductive performance: summary table ... 50
Table 7: Distribution of the 119 caesarean sections studied ... 57
Table 8: The effect of the caesarean section number and suture group on the calving interval: the Kruskal-Wallis test results (n=86, DM-BB, ILVO) ... 61
Table 9: The effect of the caesarean section number and suture group on the calving interval: the two-way ANOVA test results (n=86, DM-BB, ILVO) ... 62
Table 10: The effect of the caesarean section number and suture group on the calving interval: the ANCOVA test results(n=86, DM-BB, ILVO) ... 62

Table 11: The effect of the caesarean section number and suture group on the breeding interval: Kruskal-Wallis test results (n=85, DM-BB, ILVO) 65
Table 12: The effect of the caesarean section number and suture group on the breeding interval: ANOVA test results (n=85, DM-BB, ILVO) 66
Table 13: Analysis of the culling rate: Kruskal-Wallis test results (n=33, DM-BB, ILVO) ... 68

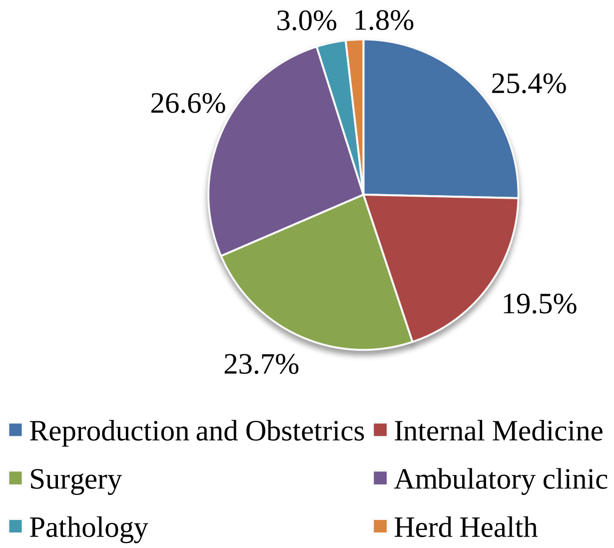
List of abbreviations

€	Euro
AI	Artificial Insemination
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
CS	Caesarean section
DM-BB	Double-muscled Belgian Blue
DNA	Deoxyribonucleic acid
FSH	Follicle-Stimulating Hormone
GnRH	Gonadotropin-releasing hormone
ILVO	Institute for Agricultural and Fisheries Research
Kg	Kilogram
LH	Luteinizing hormone
mh	Muscular hypertrophy
p	Significance value
PGF2α	Prostaglandin F2α
R^2	Determination coefficient
σ_g	Genetic standard deviation

I. Training activities' report

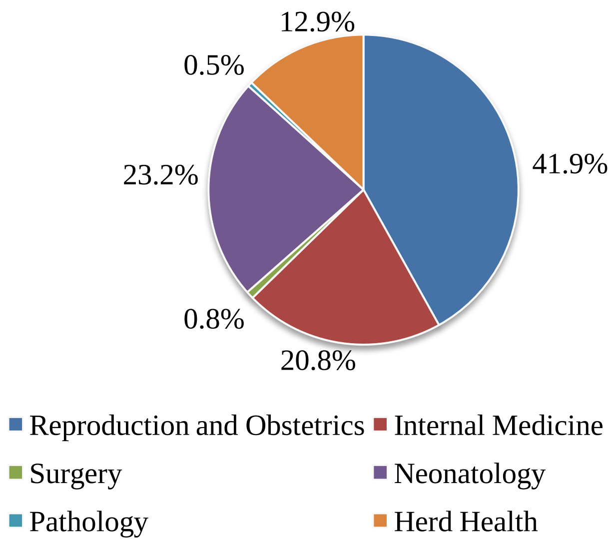
After five years of university courses, the students have to perform a training period. In our case, this stage was fulfilled at the Faculty of Veterinary Medicine, Ghent University, Belgium, and Vettotal - Serviços Veterinários, Lda., Portugal. From September 09th to December 09th 2013, the student was in Belgium to realize the Bovine Erasmus. This program consists in a 12 weeks period, with day and night shifts, to perform a rotation for all the departments from the large animals' clinic. Consulting the graphic below (Graphic 1) it is possible to understand that the departments where the student spent more time were Ambulatory Clinic (26.6%), Reproduction and Obstetrics (25.4%) and Surgery (23.7%), which contrast with Pathology (3.0%) and Herd Health (1.8%).

Graphic 1: Cases distribution in the Bovine Erasmus in Belgium



After that, from January 06th to April 25th 2014, the student accompanied the veterinary surgeon Rui Silva, DVM, from the Vettotal - Serviços Veterinários, Lda. During this period of ambulatory clinic, it was possible to observe various aspects of Veterinary Medicine in beef and dairy cattle. In this case, the most part of the casuistry focus on Reproduction and Obstetrics (41.9%) (graphic 2); these results are surely dependent on the training period - Belo, Belo, Felício and Martins (2013) in a 8 years study that included 19 768 calvings showed that in this geographic area 66% of the calvings occur between January and May. More specifically, the authors observed that 48% of the calvings occur in February, March and April. Belo et al. (2013) explained that the calving concentration during this period, in the cases where there is a permanent presence of the reproductive males, indicates that the alimentary regimen is really dependent of the natural pasture availability, permitting the calf suckling and body condition recuperation to the next reproductive season.

Graphic 2: Cases distribution in Vettotal - Serviços Veterinários,



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1. Training activities' in the Bovine Erasmus in Belgium

As mentioned before, the training period in Belgium consisted in a 12-week program with 820 hours during which the student had the possibility to realize different activities in all the departments from the large animals' clinic. The shifts are divided in day (from 8am until 5pm) and night (from 5pm until 8am), except for one week in the Reproduction and Obstetrics department where the students have a day and night shift (from Monday 8am to Monday 8am). Excluding the Pathology clinic, the Ambulatory clinic day shift and the Operation shift that works from Monday to Friday, all the others include shifts in the weekend.

During this training period, the student performed one week in day shift and one week in day and night shift in the Reproduction and Obstetrics department. The first activity in the morning was the stabled animals' physical examination, in which the student participated. During the shift it was important to monitor some Belgian Blue Beef Cattle to control the signs of labour in order to know when to perform the elective caesarean section. Therefore, it was possible to assist some of these surgeries, including the preparation of the cow and the surgical theatre, and to practice neonatal management that included administration of colostrum, feeding and prophylactic measures. There was also the possibility to perform a suturing technique of the uterus with a single modified Cushing suture pattern.

The reproductive control of the faculty's experimental station mares is also realized in this department. Therefore, the student had the possibility to practice some reproductive examinations by transrectal palpation and ultrasonography and to observe embryo collections from mares. As an interesting case, it was possible to follow, by the same methods, an ovarian mass in a heifer. Concerning the stallions it was possible to observe some semen collections and understand its evaluation and preparation for freezing and storage.

In the Internal Medicine department the student had to perform one day shift week and one night shift week. As in the Reproduction and Obstetrics department, the stabled animals' physical examination was realized. During the clinic, the student participated in some medical appointments helping with the physical examination and collaborating in additional diagnostic tests such as endoscopies and electrocardiograms. In this area it was possible to assist the follow up of the first donkey with a pacemaker.

In the Internal Medicine hospital work the student realized physical examinations, fed the animals and administered drugs in the various routes of bovines and horses and walked the horses. It was also necessary to take and analyse blood samples and control fluid therapy, procedures that were intensively realized during the equine atypical myopathy outbreak that occurred in Belgium in 2013. In the cases' discussions the gastrointestinal problems in cattle were approached.

The surgery rotation consisted of two weeks during the day (one in operation shift) and one week during the night. In this department the student had the possibility to assist to various surgeries in bovines and horses. To perform the surgery it was necessary to prepare the operating theatre and to help in the anaesthesia (induction, control during the surgery and recovery). In the operation shift it was furthermore possible to participate as an assistant surgeon in some surgeries that included a cow's laparotomy and calf's laparotomy. In this department the student realized the practical exercise that allowed the students, in groups of 3 persons, to perform a cecum resection; and gave support in the surgical placing of a venous catheter in pigs for a human medicine experiment.

In the hospitalization of the Surgery department the student realized physical examinations, fed the animals, administered drugs in the various routes and walked the horses. Furthermore, there was the opportunity to participate in a case discussion about spastic paresis.

In the Surgery department also exists a component of lameness that permitted the student to assist some procedures that included specific physical examination and additional diagnostic tests as radiology and ultrasonography.

In the Ambulatory clinic the student realized two weeks in day shift and one week in night shift. In this department the students go to the farms in the faculty cars. Therefore, the student participated in some medical appointments in beef and dairy cattle, helping with the physical examination, additional diagnostic tests, like transrectal examination, and drugs administration. The claw trimming was also done in multiple farms and so there was the chance to see some hoof diseases. As a consequence, on this department, the case discussion was about sole ulcer. As an interesting case, the student observed the slaughter of a steer with a broken leg according to legal procedures, after which the animal was transported to the slaughterhouse. There was also the opportunity to participate in a practical exercise about caesarean sections, which was a complement to surgeries that were realized in the farms also during these weeks.

In the Pathology department the students have the opportunity to perform necropsies in ruminants, horses and small animals. Therefore, during one week shift, there was the possibility to realize the necropsy technique in adult cattle, calves and sheep, while analysing all the body departments and taking samples. By the end of the day the various cases were always discussed.

The Herd Health department works by periodic visits to farms where the veterinary surgeon guides the farmer to help him in multiple areas. Thus, the student performed three visits participating in different activities that include reproductive control, dehorning and nutritional advise.

Concerning the reproductive control, the students that participate on the visit, after the transrectal examination and ultrasonography of some selected cows and with the information performed by the veterinary surgeon, examine the data of the record-keeping system. The purpose is to evaluate the fertility status of the herd, where the students use the recommendations of De Kruif and Akabwal (1978). According to these authors, the fertility level of a herd is determined by three parameters: first service conception rate, number of services per conception and interval from parturition to conception. Although it is mentioned that these parameters can be influenced by many factors, the fertility level, or status, of a herd can be expressed numerically using a Fertility Status (F.S.) formula proposed by De Kruif (1975)[1] that is cited on this article:

$$\text{F.S.} = \frac{\text{First service conception rate}}{\text{Number of services per conception}} - (\text{Interval from calving to conception} - 125)$$

Thus, the student collected the data, analysed it using the formula above and examined the results in order to conclude the reproductive health of the herds.

[1] De Kruif, A. (1975). Fertiliteit en subfertiliteit bij het vrouwelijk rund. Ph. D. Thesis. Utrech: Rijksuniversiteit te Utrecht.

2. Training activities' at Vettotal - Serviços Veterinários, Lda.

The training period in Portugal consisted in the accompaniment of the practicioner Rui Silva, DVM, from the Vettotal - Serviços Veterinários Lda., in his daily ambulatory clinic, where the student realized a total of 1 100 hours. During this time, 692 cases were observed, being 90.9% of beef and dairy cattle. The other species include swine (16 cases), sheep (16 cases), goats (12 cases), equidae (11 cases) and dogs (8 cases).

As it was shown above (Graphic 2), the Reproduction and Obstetrics cases represented 41.9% of the casuistry, which correspond to 264 cases. In this area, deserves special emphasis the 131 calving that include 15 caesarean sections and 2 fetotomy. During these procedures the student had the opportunity to learn and realize the approach to an obstetric case, including vaginal examination. When vaginal delivery was performed, the student helped the veterinary surgeon to do traction with the application, in most part of the cases, of a calf puller. In the caesarean sections, the student acted as an assistant, providing the instruments and suturing material and helping to pull out the calf. In both cases, when necessary, the student realized procedures for calf resuscitation. Other cases in this department included uterine torsions where it was possible to observe a resolution by foetus rotation *per vaginam* in contrast with "rolling" correction in another case; and several cases of uterine prolapses with the opportunity to perform a Bunher suture technique. There was also the possibility to participate in a workshop about embryo transfer where procedures, involvement and applications and advantages and disadvantages of the technique were discussed.

During this period 23 reproductive controls were performed through the use of the transrectal manual examination and/or ultrasonography. Therefore, the student had the opportunity to practice the transrectal manual examinations technique and to learn some references about ultrasonography, which include evaluation of the ovarian and uterine structures, anatomy of the embryo, gestation length, viability and sex determination. Moreover, in these visits the veterinary surgeon also evaluated other parameters that reflect the health of the herd, such as the food, faeces and body condition score.

With respect to bulls, 23 breeding soundness evaluations were performed, where the student had the possibility to participate in the animals' physical examination, semen collection and evaluation. In this area there was not just the opportunity to improve the knowledge about the principles of the male's reproductive system and the physiology that is behind the breeding soundness evaluations, but also to exercise the sperm evaluation. It was possible to observe a case of a rare middle piece defect.

The Neonatology area had also a great representation during this period, representing 23.2% of total cases with 82.9% cases corresponding to calf diarrhoea. In this area the student had the possibility to perform the physical examination to evaluate the calf health, to identify possible agents involved and to understand the principles of the therapy. According to Martins (2011) that studied the calf scours in Odemira council (n=33), the most prevalent agent is *Cryptosporidium spp.* (66.7%), which can occur in simple (73% of the simple infections) and mixed infections. This prevalence is explained not only by the high frequency of the agent, but also by the edaphoclimatic conditions that occur in this area. The same author mentioned that the mixed infections represented 48.5% of the cases and tended to involve Coronavirus or Rotavirus.

The Internal Medicine cases' corresponded to 20.8% of the total casuistry. In this department, there was the opportunity to perform the physical examination, help in the realization of some additional diagnostic tests and understand the diagnosis and consequent therapy. The most prevalent were the gastrointestinal tract problems (n=39), followed by locomotor system (n=25), that include claw trimming, and respiratory system (n=23). Here it is important to emphasize the interstitial atypical pneumonia as acute bovine pulmonary oedema and emphysema that occur in consequence to the change from dry, sparse forages to lush green pastures. This disease is caused by the conversion of L-tryptophan ingested in the lush forages to a pneumotoxic compound, the 3-methylindole (Smith, 2009). Other cases included urinary problems (n=10) where it was observed not only cronical renal failure and cistitis in adult cattle, but also leptospirosis in calves. The cases of leptospirosis occurred as an outbreak during the training period as a consequence of the climatic conditions.

As shown in Graphic 2, the Surgery department represents 0.8% of the total cases. In this area, the student had the possibility to participate as an assistant in some surgeries, helping to create a sterilized area and, during the surgery, providing the instruments and suturing material. There was the opportunity to assist a case of a left-side displacement of the abomasum.

The Pathology department represents 0.5% of total cases. This percentage includes not only euthanized animals but also the necropsies realized. In this area it was possible to practice the necropsy technique, being of special relevance the case of a calf with heart failure.

The Herd Health department corresponded to 12.9% of all the casuistry. Here it is included the annual sanitary interventions in the bovine, caprine and ovine herds, vaccinations and dewormings. Therefore, the student participated in data organization, blood sampling and vaccination and other products administration.

II. Introduction

In cattle production, beef or milk, a good reproductive performance is essential to the herd's efficiency. In beef herds' case, the calf is the major product and so the maximum reproductive efficiency is paramount in determining profitability (Ball & Peters, 2004).

In a large number of cattle farms, reproduction is not optimal, which may have an important negative effect on the herd's economy (De Kruif, 1978). Therefore, it is essential to understand the factors that influence reproductive performance and how they can be manipulated to achieve the main goals.

Factors of genetic or environmental nature affect the reproductive performance, including the parity or age of the dam and the occurrence of dystocia (Short, Bellows, Staigmiller, Berardinelli & Custer, 1990; MacGregor & Casey, 1999; Carolino, Gama & Carolino, 2000). According to Carolino et al. (2000) the age of the dam has a quadratic effect in the calving interval, being greater in heifers and in cows with more than 8 years old. In what concerns to caesarean section, Hanzen, Laurent and Ward (1994) showed its effect on reproductive performance, including an increased interval from calving to first oestrus, number of services per pregnancy and days open.

According to Kolkman (2010) in the double muscled Belgian Blue breed 90% to 95% calves are born by caesarean section. So, the main goal of this work was to understand the influence of this procedure in the reproductive performance, specifically in the calving interval, breeding interval and culling rate, at different ages of the dam and using different suture materials.

III. Literature review

1. Breeding goals in beef cattle

Animal breeding is part of the production (long-term) strategic planning and is aimed at changing the genetic merit of animals in coming generations so that they will produce the desired products more efficiently (relative to the present generation) under future economic, natural and social circumstances (Groen et al., 1997).

Phillips (2010) explained that the breeding objectives in beef cattle take into account various parameters. The feed utilization efficiency is very important in beef cattle production systems, as this parameter factor about 80% of variable costs. Thus, the author mentioned that improving the efficiency of beef cattle production is usually directed to the reduction of feed conversion ratio. Another relevant objective is the carcass traits. In fact, it is possible to select for the inclusion of carcass weight, which has a good heritability, and eye muscle area, rib or rump fat, all with moderate heritability. A genetic mutation occurs in the Belgian Blue and Piedmontese breeds, which increases the rate of muscle growth by interfering with the regulator myostatin. It is important to notice, as Phillips (2010) clarified, that in Belgian Blue cattle, this trait is associated with difficult calving in pure-breed animals and the increase cost of care during calving may be financially justified by increased growth rate potential, but the practice arouses concerns for the cows' welfare. Another aspect referred by the author is the reproductive traits, since the low reproductive rate of many beef cows encourages breeders to include this characteristic in breeding programmes. Finally, Phillips (2010) mentioned that, apart from the characteristics focused on the productive potential, there are some breeders that include on their goals the environment and welfare, structural traits related to cattle form and function and economic traits, on the latter case just to increase profit per animal rather than for specific traits.

In cattle production, good reproductive performance is essential for efficient management and production as a whole, although specific reproductive targets may depend to some extent on local conditions and on individual farm systems and goals (Ball & Peters, 2004). Azzam, Kinder and Nielsen (1990) explained that beef cattle are traditionally mated during breeding seasons of defined length and at the time of the year that will optimize subsequent calf survival and growth under constraints imposed by feed costs. The same authors remarked that timing of breeding season is also influenced by marketing alternatives for the calves.

Reproductive efficiency can be described as a measure of the cow's ability to become pregnant and produce viable offspring (Ball & Peters, 2004); and the results from Aby, Vangen, Sehested and Aass (2010) showed that fertility and other reproduction traits are the most important to consider in the semi-intensive beef cattle production systems with a basic relative economic value of 75.02%. In fact, several authors emphasized the importance of a good reproductive efficiency. Ball and Peters (2004) referred the analysis from the Meat and Livestock Commission. According to this data, the difference between a conception rate at first service from 75% to 40%, at a growth rate of 1 kg/day and a sale price of 1.28€/kg, means a difference of 29€ per head. Amer, Lowman and Simm (1996) also analyzed this parameter, referring that one percent increase in the conception rate at first postpartum oestrus can lead to a difference between 0.13€ to 0.90€ per cow.

Koots and Gibson (1998) studied the reproductive traits demonstrating the estimated economic value of the input traits in a pure breeding or rotational crossing system and in a dam line. The values were in euros (€) per genetic standard deviation (σ_g) per cow to give a better indication of the relative potential for economic change considering the genetic selection. Therefore, they concluded that in the first system the bigger economic value is the percentage of calf survival with a difference of 21.91 € σ_g^{-1} cow^{-1}, while the cow fertility is the second one with an influence of 18.39 € σ_g^{-1} cow^{-1}. In the dam line, the cow fertility is the parameter that assumes the biggest value with 23.19 € σ_g^{-1} cow^{-1} followed by the percentage of calf survival that costs 22.63 € σ_g^{-1} cow^{-1}. These results are in line with what was found by Aby et al. (2010) who stated that the most important trait in the group of fertility and other reproductive traits it is the stillbirth (70.79%).

Therefore, taking into account the aforementioned, the maximum efficiency is most often achieved when replacement heifers calve by 24 months of age without any complications and deliver a live calf every 12 months thereafter until reaching the economically optimal time for culling (Gates, 2013). For seasonal grazing herds, however, it is particularly important to maintain tight calving distributions less than 12 weeks to minimize labour costs, to ensure that changes in pasture quality coincide with changes in the nutritional demands of lactating animals, and to produce more uniform calf groups for fattening, with higher weight and age at sale (Ball & Peters, 2004; Gates, 2013).

2. Reproductive Health Programs for Beef Herds: the measurement of reproductive efficiency

In order to maximize efficiency, and specifically reproductive efficiency, in a dairy or beef herd, the farmer should (1) develop a series of targets, (2) manage the herd and individual cows to best achieve those targets efficiently and (3) evaluate performance on a regular, ongoing basis, in order to correct problems before they have a too serious impact on the attainment of the targets (Ball & Peters, 2004). It is then an important point to understand reproductive health management. The breeding goals will be discussed during this chapter and tables 1 to 4 show the values proposed by Morrow (1980) (for dairy cattle) and Rice (1986) (for beef cattle).

Table 1: The replacement heifer breeding efficiency (Morrow, 1980; Rice, 1986)

Parameter	Breeding goal
Breeding age	13 to 15 months
Breeding weight	65 % of their mature weight
Per cent cycling first 21 days	85%
Per cent pregnant after 42 days	85%
Age at first calving	24 months

Table 2: The adult cow breeding efficiency (Morrow, 1980; Rice, 1986)

Parameter	Breeding goal
Per cent cycling first 21 days	90%
First service conception rate	70%
Per cent pregnant cows	95%
Calving interval	< 380 days

Table 3: Calf survival (Rice, 1986)

Parameter	Breeding goal
Calf survival at birth	95%
Nursing survival	95%
Per cent calf crop weaned	85%

Table 4: The culling rate (Morrow, 1980)

Parameter	Breeding goal
Involuntary	< 10%
Voluntary	< 15%
Total	< 25%

2.1. The age at first calving

The age at first calving is a combined measure of the time taken to raise replacement heifers to breeding maturity, the success in getting heifers pregnant in a timely fashion, and the ability of heifers to deliver a viable calf, being considered that the replacement heifers should calve by 24 months (Morrow, 1980; Gates, 2013). Nevertheless, the Chambres d'Agriculture des Pays de la Loire (2010) mentioned that in beef cattle it is possible to adapt the grow rate to the age at first calving so it occur at 24 months, 30 months or 36 months. The first calving at 24 months is not usually observed in this region. In fact, however it is a possibility to increase de productivity, it requires enough weight (60% of the mature weight) at the breeding season so the heifers are cycling and therefore can be bred and enough weight at calving (80%

of the mature weight) to minimize the dystocia incidence. In what concerns to the 30 months age at first calving, it is usually privileged when there are two breeding seasons, increasing the economic efficiency of the productive system (in comparison with the 36 months) with a small impact in the zootechnical performances and moderate growth rates, while decreasing the dystocia risk. The 36 months age at first calving takes advantage of the compensatory growth, being that the animals can calve with 90% of their mature weight.

A primary determinant of pregnancy success in the first breeding season of a heifer is the time at which puberty occurs relative to the start of its first breeding season. The effect of calving distribution on beef cattle progeny performance was studied by Funston, Musgrave, Meyer and Larson (2012), who conclude that the heifer birth weight was lightest ($P < 0.01$) for heifers born in the first period as well as the birth to weaning average daily gain ($P = 0.10$). However, weaning weight decreased ($P = 0.03$) with advancing calving period (217kg, 212kg, and 195kg, respectively, for first, second, and third 21-day period) and the pre-breeding weight was greatest ($P < 0.01$) for calves born in the first period (294kg, 290kg, and 274kg, respectively, for first, second, and third 21-day period). Thus, the percentage of heifers cycling at the beginning of the breeding season decreased ($P < 0.01$) with advancing calving date (70%, 58% and 39%, respectively) and 45-day pregnancy rates were lower ($P = 0.02$) for heifers born in the third calving period (90%, 86% and 78%, respectively).

The first breeding season affects the heifer's ability to rebreed in ulterior years and remain in the herd as well as the productive life (Day & Nogueira, 2013). Rice (1986) mentioned that heifers that calve late in the first year always tend to calve late in subsequent years or have a greater tendency not to get pregnant. Cushman, Kill, Funston, Mousel and Perry (2013) analyzed data from the United States Meat Animal Research Centre and concluded that heifers that calved with their first calf during the first 21-day period of the calving season had increased longevity ($P < 0.01$) compared with heifers that calved in the second 21-day period, or later. The average longevity for the heifers that calved in the first, second, or third period was 8.2 ± 0.3 years, 7.6 ± 0.5 years and 7.2 ± 0.1 years, respectively.

Therefore, Rice (1986) indicates that to start a breeding program integration, an heifer should have 65% of its mature weight at 13 to 15 months of age, at the beginning of its breeding season, expecting an 85% to 90% of those to be cycling. Furthermore, the replacement heifers should be bred during a 42-day breeding season, starting 21 days before the cows. Thus, it is expected a high reproductive performance on this class, with a goal of 85% heifers cycling and bred on first 21-days and 95% by the end of 42-days. In addition, 85% heifers bred should become pregnant after the 42-days (Rice, 1986).

2.2. The calving interval and calving index

After breeding, conception and delivery, it is important, as mentioned above, that the female calves every 12 months, until reaching the economically optimal time for culling, which is measured taking into account the calving interval and the productive lifetime.

According to Noakes, Parkinson and England (2009), it is possible to define calving interval and calving index. The calving interval is the interval (in days) between successive calvings for the same cow, which, according to Gates (2013), reflects the time taken for animals to return to oestrus, to be successfully re-bred after calving and to deliver a viable calf; the calving index is the mean calving interval of all the cows in a herd at a specific point in time, calculated retrospectively from their most recent calving date.

Noakes et al. (2009) clarified that the calving interval and calving index are measurements that have been traditionally used as a measure of fertility, since they indicate how closely the individual cow or herd approximates to the accepted optimum of 365 days. A more realistic goal of 380 days has been suggested by Morrow (1980).

Several researchers (Youngquist & Threlfall, 2007; Noakes et al., 2009) demonstrated inadequacies of the calving interval, because this parameter introduces bias by excluding populations (culled cows, first-lactation animals, animals pregnant but not yet calved, "do not breed" cows) and requires two consecutive calving dates. Furthermore, on a herd calculation basis, events from as much as two years before still enter into the current calculation, and it is a historical value calculated retrospectively. In what concerns to the calving index, this value does not take into account the fertility of heifers and can give an overoptimistic assessment of fertility when many of the cows that fail to become pregnant are culled (Noakes et al., 2009).

2.3. The calving to conception interval and days open

After a gestation period of approximately 280 days, cows have to establish a pregnancy within 85 days to achieve the goal already proposed of 365 days between successive calvings. Noakes et al. (2009) defined this parameter as the calving to conception interval, which is the number of days from calving to the service that result in pregnancy (effective service). However, the authors mentioned that this is influenced by two factors: how soon after calving the cows are re-bred and how readily they become pregnant when they have been served. So, the calving to conception interval can be defined as the sum of the mean calving to first service interval and the mean first service to conception interval. In the records analysis for reproductive Herd Health programs, Morrow (1980) mentioned that the interval from calving to first oestrus should be less than 60 days and the mean number of services per pregnancy should be less than 2. In beef cattle, Rice (1986) referred that the producer expect the cow to be pregnant by 90 days or less after calving, but 60 to 80 days of postpartum rest are necessary for 80% beef cows start cycling.

The days open is defined as the interval, in days, from calving to subsequent effective service date from those cows that conceive, and from calving to culling or death for cows that did not conceived. Numerically, this value will always be greater than the mean calving to conception interval unless all the cows that are served conceive, in which case it would be the same (Noakes et al., 2009). Therefore, Morrow (1980) referred that the breeding goal should be less than 100 days open.

Noakes et al. (2009) defined that the factors that influence the calving to first service, and then to conception, are the breeding policy of the farm, the failure to detect oestrus in cows having resumed normal cyclical activity and the delayed return to cyclical activity, which is going to be subsequently approached.

2.3.1. The postpartum period in beef cattle

Parturition is followed by a period, about three weeks in cows, when conception is not possible because uterine involution is still going on. Although oestrus and ovulation can occur during this time, if fertilization happens and the embryo reaches the uterus, the placentation and sustaining embryo developing would be virtually impossible. Furthermore, the period of no fertility is followed by two to three weeks when fertility is possible, but not optimal (Kiracofe, 1980; Noakes, 1986).

There are four main areas of activity during the postpartum period, which include: the uterine involution; the structure of the endometrium and deeper layers; the bacterial contamination; and the ovarian function (Noakes et al., 2009).

In the polyoestrous species, such as the cow, it is important that this period progress normally since the practice under most systems of husbandry is to breed the animals fairly soon after they give birth. Thus, Noakes et al. (2009) emphasized that any extension may have a detrimental effect on the reproductive performance of the individual animal concerned. In fact, Senger (2003) also reinforced that the shorter the interval between pregnancies, the more offspring are produced and the more efficient the meat production becomes.

The definition of puerperium is controversial among authors. According to Senger (2003) the puerperium begins immediately after parturition and lasts until reproductive function is restored so that another pregnancy can occur. Noakes et al. (2009) defined the puerperium as the period after the completion of parturition, including the third stage of labour, when the genital system is returning to its normal non-pregnant state. In contrast, Youngquist and Threlfall (2007) referred the puerperium as the involution of the previously gravid uterus.

As mentioned before, during this period, there is a reduction in the size of the genital tract that occurs in a decreasing logarithmic scale, the greatest change being observed during the first few days after calving. Uterine contractions continue for several days, although decreasing in regularity, frequency, amplitude and duration (Noakes et al., 2009). The time that is needed to observe a complete uterine involution varies according to the authors. Noakes et al. (2009) cited three studies in beef cattle that reported a range between 37.7 to 56 days, while Senger (2003) pointed 30 days. Yavas and Walton (2000) referred a length of time from 28 to 42 days in suckled beef cows, but explained that uterine involution is influenced by several factors, suckling being an example of an element that positively affects this process. In fact, the tactile stimuli to the inguinal area of the cow by the calf during attempted suckling, in addition to tactile stimulation of the teats *per se*, induce release of oxytocin. This hormone generates "milk ejection" and stimulates prostaglandin F2α (PGF2α) release from the uterine endometrium.

The purpose of the uterine contractions that occur during this period is threefold (Senger, 2003): promote the discharge of fluids and tissue debris from the uterus; compress the uterine vasculature and help to minimize the possibility of haemorrhage; and reduce the overall size of the uterus. Therefore, involution occurs as a shrinkage and atrophy of the tubular genital tract, especially the uterus, thus reversing the hypertrophy that occurs in response to pregnancy stimulus (Noakes et al., 2009).

Caruncular repair requires vasoconstriction, necrosis and sloughing of tissues followed by growth of surface epithelium. After separation of the foetal cotyledon from the maternal caruncle (within 8 to 12 hours after delivery of the neonate) vasoconstriction takes place in the stalk of the maternal caruncle. Necrosis of the caruncular tissue follows with a sloughing of the caruncular mass, leaving necrotic tissue in the lochial fluid inside the uterus (Senger, 2003).

Although the placenta in cow is considered to be non-deciduous, it is well recognised that during the first 7 to 10 days after calving there is usually a noticeable loss of fluid and tissue debris. The lochia discharge is derived from the remains of foetal fluid, blood from ruptured umbilical vessels and shreds of foetal membranes, but mainly from the sloughed surfaces of uterine caruncles. This fluid is usually characterized by a yellowish brown or reddish brown colour, without an unpleasant odour, with a volume that varies greatly from individual to individual. The greatest flow of lochia occurs during the first 2 to 3 days; by day 8 it is reduced, and by days 14 to 18 postpartum it has virtually disappeared (Noakes et al., 2009).

After the decidual tissue of the caruncle has sloughed into the uterine lumen, it begins to undergo repair and is eventually covered again with endometrial epithelium (Senger, 2003).

The re-epithelialisation of the caruncle is complete from 25 days onwards, although the stage at which complete healing occurs is variable (Noakes et al., 2009). At the same time, the intercaruncular surfaces also undergo repair, which is generally complete by the 8^{th} day postpartum (Senger, 2003; Noakes et al., 2009).

At calving, and immediately postpartum, the vulva is relaxed and the cervix is dilated thus allowing bacteria to gain entry into the vagina, and thereafter the uterus (Noakes et al., 2009). Furthermore, generally, parturition occurs in a non-sterile environment, which results in the reproductive tract bacterial contamination, especially the uterus, as inevitable sequel of parturition (Senger, 2003).

Foldi et al. (2006) referred that a wide variety of bacteria can be isolated from almost all cows during the first 10 to 14 postpartum days. These authors elucidated that bacterial presence in the uterus is usual at this time and can be detected in more than 90% of the cows, regardless of disease signs. *Escherichia coli* and *Trueperella pyogenes* are the most prevalent bacteria isolated from the uterine lumen of cattle with uterine disease, followed by a range of anaerobic bacteria such as *Prevotella* species, *Fusobacterium necrophorum* and *Fusobacterium nucleatum* (Sheldon, Cronin, Goetze, Donofrio & Schuberth, 2009).

Despite uterine contamination, several studies referred that the percentage of uteri from which bacteria are isolated decreases with time (Noakes et al., 2009). In dairy cattle, Sheldon et al. (2009) showed that after 30 days, almost 80% of the animals had uterine bacteria and at day 60 approximately 30%. Nevertheless, Elliot, McMahon, Gier and Marion (1968) [2] demonstrated that the percentage of animals with uterine contamination decreased from 93% within 15 days of calving to 78% between day 16 to 30 and to 50% between day 31 and 45; only 9% of the animals presented uterine contamination on day 60 (Noakes et al., 2009). This reduction in the uterine contamination is explained by a rapid involution of the uterus and cervix and discharge of uterine content, that promote a physical expulsion of the bacteria, and mobilization of natural host defences, including mucus, antibodies and phagocytic cells. In fact, the main mechanism involved in the elimination of the bacteria is phagocythosis by migrating leucocytes (Azawi, 2008). Therefore, in most of the cases, early return to cyclical activity is probably important since the estrogens-dominated uterus is more resistant to infection (Noakes et al., 2009).

In some instances, high numbers of bacteria can overwhelm the natural defence mechanisms resulting in postpartum uterine infection. Senger (2003) explained that conditions that predispose the uterus to infection are: retained foetal membranes, dystocia and delayed lochial

[2] Elliot, L., McMahon, K., Gier, H. & Marion, G. (1968). Uterus of the cow after parturition: bacterial content, *American Journal of Veterinary Research*, 29, 77-81.

expulsion, which prolong the uterine involution and the postpartum period and, accordingly, delay subsequent pregnancy.

Except during the last month, anovulatory follicular waves occur periodically during pregnancy, with the emergence of follicles up to a maximum of 6 mm in diameter. However, because of the prolonged period of inhibition, due to the continuous negative feedback effect of progesterone secreted by the *corpus luteum* and placenta, the pituitary is refractory (Noakes et al., 2009). Therefore, the lack of ovulation of dominant follicles during the postpartum period is associated with infrequent luteinizing hormone (LH) pulses, with major factors as maternal bond/calf presence, suckling and low level of nutrition being implicated in the prolonged suppression of LH pulses in the absence of progesterone (Yavas & Walton, 2000; Crowe, 2008). So, the postpartum anoestrous can be defined as a transition period during which the functional hypothalamic-pituitary-ovarian-uterine axis recovers from the previous pregnancy (Yavas & Walton, 2000).

During late gestation, the hypothalamic-pituitary axis is under the negative feedback of the placental and ovarian steroids, which results in accumulation of Follicle-Stimulating Hormone (FSH) in the anterior pituitary, suppression of FSH release, depletion of anterior pituitary LH stores and suppression of ovarian follicular activity (Yavas & Walton, 2000). After parturition, and as consequence of the foetal-placental unit removal and by the *corpus luteum* regression, there is almost immediate resumption of recurrent transient increases in FSH concentrations (within 3 to 5 days of parturition) that occur at 7 to 10 days intervals (Yavas & Walton, 2000; Crowe, 2008). The first of these stimulates the first postpartum follicular wave that generally produces a dominant follicle by 7 to 10 days postpartum (Crowe, 2008).

The first follicular wave's dominant follicle fate is dependent on its ability to secrete sufficient estradiol to induce a gonadotrophin surge (Crowe, 2008). However, the ability of the pituitary to release LH is much slower. Due to depletion of anterior pituitary LH storage during late gestation, anterior pituitary LH content is reduced by 95% at parturition (Yavas & Walton, 2000). Thus, the major driver for ovulation of a dominant follicle during the post-partum period is the LH pulse frequency (Crowe, 2008). Ovulation will occur only if the dominant follicle produces enough estradiol to stimulate adequate LH secretion in the form of one pulse per hour (Crowe, 2008).

In suckler beef cows, the first dominant follicle generally does not ovulate, but rather undergoes atresia. In fact, the first postpartum dominant follicle to ovulate is generally from wave 3.2 ± 0.2 (≈30 days). This first ovulation can be generally characterized as silent and followed by a short cycle, usually containing just one follicle wave (Crowe, 2008). The absence of the oestrus signs demonstration can be justified by the requirement of the Central Nervous Systems to prior exposure to progesterone to elicit behavioural signs (Noakes et al., 2009). A short cycle can happen in 78% of suckler beef cattle and it is due to a premature release of PGF2α, which results in premature luteolisys (Yavas & Walton, 2000; Crowe, 2008). Thus, the *corpus luteum* regresses prematurely at approximately days 8 to 10 of the cycle, with the second ovulation occurring approximately 9 to 11 days after the first ovulation. This second ovulation is generally associated with the expression of oestrus and a normal length luteal phase (Crowe, 2008).

2.3.2. Major factors affecting the postpartum in beef cattle: the calf and the body condition

As mentioned before, the major factors that affect the length of the postpartum are the low level of nutrition, maternal bond/calf presence and suckling, which lead to a prolonged suppression of LH pulses in the absence of progesterone.

Relationships between body energy reserves and weight loss (before and after parturition) and the duration of the postpartum anoestrus have been established. In fact, energy intake and body energy stores influence concentrations of energy substrates and metabolic hormones in cattle blood (Wettemann, Lents, Ciccioli, White & Rubio, 2003).

The influence of the nutrition in the postpartum anoestrus is mediated by potential metabolic signals that include glucose, insulin and Insulin-Like Grow Factor-I (IGF-I) (Wettenann et al., 2003).

According to Pineda and Dooley (2003) there are receptors for insulin in the brain, pituitary gland and ovarian tissue. Experiments showed that this hormone stimulates release of Gonadotropin-releasing hormone (GnRH) from hypothalamic fragments *in vitro* when glucose is available and also that it stimulates the steroid production by ovarian cells. The hypothalamus, unlike other areas in the Central Nervous System, expresses an insulin-dependent glucose transporter. During nutritionally induced anoestrus, cows become resistant to insulin and entry of glucose into hypothalamic cells may be reduced (Pineda & Dooley, 2003).

The IGF-I is mostly produced by the liver and has effects on many cell types to regulate carbohydrate, fat and protein metabolism. During feed restriction, concentrations of IGF-I in cattle blood are decreased, which affect its action in the potentiation of FSH on granulosa cells of ovarian follicles and LH on thecal cells of ovarian follicles and luteal cells (Pineda & Dooley, 2003).

Several studies cited by Wettemann et al. (2003) about the nutrition and postpartum endocrine function concluded that the body energy reserves at calving is the most important factor that influences the interval from parturition to the first oestrus and ovulation in beef cows. Actually, since postpartum cows have to be in good body condition at resumption of cyclicity, and since body condition postpartum score is a reflection of nutritional status prepartum, Yavas and Walton (2000) noted that postpartum reproduction is more affected by the energy intake before than after calving. However, about the postpartum nutrient intake, the studies are controversial. Yavas and Walton (2000) stated that reducing energy intake after parturition through the first 30 days postpartum or increasing energy intake after parturition through first ovulation postpartum did not affect postpartum interval. Nevertheless, Ciccioli et al. (2003), in a study with primiparous beef cows, demonstrated that postpartum nutrient intake can modulate the duration of the postpartum anestrous interval. The authors showed that this period was shorter for cows allotted to diet for gains of 0.90 kg/day ($P < 0.01$; 100 ± 8 days) than of 0.45 kg/day ($P < 0.01$; 120 ± 8 days) and justified the lack of consistency among studies with several variables like the amount of energy intake, duration of feeding period, body condition score at calving and age of cows. Although, even if thin cows gain great amounts of weight after calving, ovulation occurs later than for cows that calve in good body condition and maintain body weight (Wettemann et al., 2003).

Decreased pulsatile secretion of GnRH is the major cause of reduced pulsatile secretion of LH and extended postpartum anovulatory intervals in beef cows (Wettemann et al., 2003). Crowe (2008) mentioned that for beef cows in poor body condition there are typically 10.6 ± 1.2 waves of follicular growth before ovulation occurs (≈70–100 days). Adequate nutrient intake results in increased concentrations of insulin and IGF-I in plasma and increased body fat reserves. If fat stores are sufficient (body condition score greater than 5/9) and nutrient intake is not adequate, mobilization of fat can occur and alter plasma concentrations of these products. The studies cited in Wettemann et al. (2003) referred that the stable concentrations of insulin and IGF-I in plasma of primiparous cows during the 7 weeks before the first postpartum oestrus indicate that immediate changes in these constituents may not stimulate the first postpartum ovulation. These hormones could be metabolic signals by which nutrient intake and body fat stores regulate ovulation, but have a delayed effect, a permissive role, and/or the effect could be mediated by alterations in binding proteins or specific receptors, so that absolute changes in hormones concentrations may not be necessary for the response to occur.

After the replenishment of LH stores between days 15 and 30 postpartum, the absence of LH pulses is dependent of suckling, which suppresses pulsatile LH release by inhibiting GnRH discharges from the hypothalamus (Yavas & Walton, 2000). Álvarez-Rodriguez, Revilla and Sanz (2009) summarized that the essential component of the prolonged postpartum anoestrus induced by suckling in beef cows is the maternal-offspring bond, while independent of the neurosensory pathways within the teat or the udder. The same authors referred that olfaction and vision are equally effective in allowing the calf identification by its dam. Studies with ovariectomy and estradiol implants in postpartum cows indicated that the suppressive effect of suckling on pulsatile LH release is modulated by ovarian estrogens which is explained by the increased sensitivity of the hypothalamic GnRH pulse-generator to the negative feedback effect of ovarian estradiol-17β via release of endogenous opioid peptides from the hypothalamus. This results in suppression of pulsatile release of LH, failure of ovulation, and prolonged postpartum anoestrus (Yavas & Walton, 2000).

As the postpartum interval increases, the GnRH pulse-generator becomes less sensitive to suckling stimulus, which results in increase pulsatility of LH, preovulatory gonadotropin surges and ovulation. Yavas and Walton (2000) mentioned that in suckled beef cows, medium follicles are present by day 5 to 7 postpartum, and their numbers and size increase with time. Dominant follicles are detectable by day 10 to 21 postpartum; however, most of these dominant follicles fail to ovulate. In fact, in suckled beef cows, the pulsatile LH release recovers around day 25 to 32 postpartum and cows resume to cycling between days 29 and 67 (Yavas & Walton, 2000).

Summarizing, it is important to understand that the interval from calving to conception greatly influences profitability of beef production. According to Rice (1986), the farmer expects that the cows become pregnant by 90 days or less after calving. However, as explained by Wettemann et al. (2003), inadequate body fat stores at calving and reduced postpartum nutrient intake increase the interval from calving until ovulation. Furthermore, suckling suppresses ovulation during the early postpartum period in cows with moderate body fat stores, and the suppression is longer in thin cows. Restricted suckling or early weaning of calves can be used to improve reproductive efficiency in very thin cows (Wettemann et al., 2003).

2.4. The percentage of cows cycling during the first 21 days of the breeding season

As explained above, the calf is the major product in the beef herds' case (Ball & Peters, 2004) and several studies were undertaken to investigate the effects of the calves' birth group in their future performance.

One of the first research about this subject was performed by Lesmeister, Burfening and Blackwell (1973) and concluded that calves born in earlier groups grew significantly faster

from birth to weaning (average daily gain from 0.80 kg/day to 0.75 kg/day, $P < 0.05$) and weighed more at weaning than calves born in later groups (weaning weight from 210 kg to 160 kg, $P < 0.01$). Some years later, MacGregor and Casey (2000) studied five calving groups and obtained the same results. Although the calf birth weight was 32.81±0.33 kg on the first calving period compared to 40.49±0.30 kg on the fifth one ($P < 0.01$), the weaning weight decrease from 239.89±1.78 kg to 211.93±1.57 kg ($P < 0.01$), respectively. For the authors, this difference is explained by the fact that early born calves had higher pre-weaning average daily gains ($P < 0.01$), and are older at weaning than calves born later ($P < 0.01$).
Furthermore, Funston et al. (2012) described that calves born in the first 21 days of the calving season had greater carcass weights, marbling scores and yield grades than later born calves.
Other advantages reported on the majority of calves born early in the calving season were discussed by Ball and Peters (2004). These authors referred that calf disease and mortality are likely to be reduced if there is only small variation in calf ages and the age and weight of calves are higher at sale. Furthermore, all cows at the similar stage of the production cycle can be regarded as a single unit rather than as individuals and feed can be rationed more precisely.
Therefore, the percentage of cows cycling during the first 21 days of breeding season is an important and easy criteria to measure in beef artificial insemination herds with, according to Rice (1986), a goal of 90%. However, the author remembered that although this parameter has equal economic importance in herds using natural service, the oestrus observations is less accurate and therefore unreliable in measuring oestrus activity.

2.5. The first service conception rate and percentage of pregnant cows

It has long been recognized that, although a cow that seems to have an apparently structurally and functionally normal reproductive system is inseminated or served at the correct time with fertile semen, it may fail to become pregnant. This is partially explained by fertilization failure and embryonic losses (Noakes et al., 2009).

2.5.1. Fertilization failure and embryonic losses

An ovulatory surge of LH coincident with onset of oestrus (day 0) initiates events, which culminate in ovulation about 30 hours later. With maturation of the *corpus luteum*, concentrations of progesterone in peripheral blood are maximum in mid-diestrus (days 8-14), and, in cyclic females, luteolysis is induced by pulsatile release of PGF2α from endometrial epithelium during late diestrus (days 15-16) (Bazer, Spencer & Ott, 1997). Experiments based on daily progesterone measurements, following insemination and embryo removal at various stages after artificial insemination, suggested that embryonic death at the time of *corpus luteum* maintenance delayed luteolysis and extended interestrus interval (Humblot, 2001).

The maternal recognition of pregnancy in ruminants is mediated by the interferon τ (tau), which is produced by the mononuclear cells of the embryonic trophectoderm (Bazer et al., 1997). This protein binds to the endometrium and inhibits oxytocin receptor synthesis by endometrial cells so that oxytocin cannot stimulate PGF2α synthesis (Senger, 2003). Thus, interferon τ exerts a paracrine, antiluteolityc effect on the endometrium to inhibit endometrial production of luteolityc pulses of PGF2α (Bazer et al., 1997).

Secretion of interferon τ is maximal between pregnancy days 16 and 19, but can be detected from day 12 until at least day 38 of pregnancy (Bazer et al., 1997). Humblot (2001) suggested that luteolysis and return to oestrus prior to day 24 might be linked with early embryonic death; but, if the *corpus luteum* is maintained and return to oestrus is delayed beyond day 24, it could point to embryonic losses occurring after day 16 of gestation.

In order to properly standardize bovine reproductive terms, Hubbert (1972) established that the embryonic period of gestation extends from conception to the end of the differentiation stage, at approximately 42 days of gestation, and that the foetal period extends from gestation day 42 to the delivery of the calf. Thus, Humblot (2001) defined that losses of pregnancy prior to day 24 indicate early embryonic losses, and those between days 24 and 42-50 indicate late embryonic losses. Pregnancy losses detected after day 50 characterize foetal losses.

According to Diskin and Morris (2008) for heifers, beef and moderate yielding dairy cows, it appears that fertilization rate generally lies between 90% and 100%. Additionally, studies in heifers suggest fertilization rate averages 88%, with a range from 75% to 100%. In lactating beef cows it was reported fertilization rate averages 75%, with a range from 60% to 100%, while in non-lactating beef cows rate that value averages 98.6%, with a range from 94% to 100% (Santos, Thatcher, Chebel, Cerri & Galvão, 2004).

Concerning embryonic loss, Bishop (1964) mentioned a variable incidence from 15 to 60% according to the material source examined. More recently, Humblot (2001) referred studies with beef breeds with non-fertilization or early embryonic mortality between 33% to 39% and late embryonic mortality between 6.6% and 14%. In beef heifers, Diskin and Sreenan (1980) indicated an embryo survival rate of 58% at day 42 and Dunne, Diskin and Sreenan (2000) mentioned that it is generally accepted that in this group the embryo loss accounts for a 29% to 39% after fertilization, referring that it mostly occur between days 8 and 16 after insemination. It is important to emphasize that late embryo loss, while numerically much smaller than early embryo loss, causes serious economic losses to producers because it is often too late to re-breed those females (Diskin & Morris, 2008).

There are two main causes of embryonic loss: genetic and/or environmental factors. The exact effect of each factor depends upon when, during gestation, it is encountered and how it exerts its influence (Noakes et al., 2009). Bishop (1964) proposed that, because embryonic loss appeared to be a general feature of mammalian reproduction, it probably conferred some biological advantage that might allow the elimination of undesirable genetic material at a low biological cost. If this is true, then a considerable part of embryonic death should be regarded as a normal occurrence and thus unavoidable. This concept of inevitable conceptual loss implies a limit to the chance of a successful outcome to each mating or insemination, which will not be significantly affected by previous success or failure (Noakes et al., 2009).

Although recognizing that it is not expectable a 100% calving rate, it is important to know how to identify the embryonic loss. If fertilization occurs, the developing conceptus prevents the return to oestrus by inhibiting the production or release of PGF2α, which causes the regression of *corpus luteum* and thus the dramatic decrease of progesterone levels which precedes the return to oestrus (Ayalon, 1978; Noakes et al., 2009). Therefore, if the embryo dies before 13 days of age (the time of maternal recognition of pregnancy), the cow will return to oestrus at the normal interestrus interval. If the embryo dies after this age, then the interestrus interval will be extended beyond the generally accepted figure of 18 to 24 days. Noakes et al. (2009) clarified that it is impossible to differentiate, by observing the occurrence of return to oestrus, between fertilization failure and embryonic death before 13 days of age, because such cows will return oestrus after the same interval as unmated animals, despite having been pregnant. This is particularly important, since it has been postulated that most embryos die before 15 days of age (Ayalon, 1978) and there is good evidence that the critical period is on day 7 after fertilization when the morula develops to blastocyst (Noakes et al., 2009).

2.5.2. First service conception rate and percentage of pregnant cows: breeding goals

Taking into account the above mentioned, it is important, to measure the adult cow breeding efficiency, to evaluate at least the first service conception rate and percentage of pregnant cows (Rice, 1986). Additionally, Youngquist and Threlfall (2007) referred the calving histograms that can be used to further define the conception pattern of the herd and the expected calving distribution.

When evaluating the success of the breeding program, the traditional measure that has been most often used is pregnancy rate (Youngquist & Threlfall, 2007). Taking the number of pregnant animals in the individual group or herd and dividing it by the number of exposed females will give this value which, according to Rice (1986), has a goal of 95%.

Although this determination is somehow valuable, Youngquist and Threlfall (2007) reinforced that it gives no insight into important factors such as the length of breeding season, bull-to-female ratios, grazing conditions, or cow characteristics (age, body condition score or frame score) that have an impact on reproductive performance. Therefore, in addition, Rice (1986) referred that the 95% has a greater significance when the breeding is short, mentioning that the goal should be 63 days (three cycles breeding season) to ensure ideal weaning weights. A more complete analysis of herd performance would enable the veterinarian to judge when individual cows become pregnant and the percentage by each oestrous cycle. (Youngquist & Threlfall, 2007).

Another measurement that is especially important for all beef herds is the first service conception rate with a breeding goal that vary according to literature between 60% (Youngquist & Threlfall, 2007) and 70% (Rice, 1986) or even 60% for artificial insemination and 70% for natural mating (Christenson, Echternkamp & Laster, 1975). A combination of high conception rates and high cycling rates ensure a high percentage of calves born early in the calving season (90% cycling first 21 days x 70% conception = 63% pregnancy first 21 days), which, as referred earlier, would be beneficial (Rice, 1986).

For this measurement, it is relevant to take into account that, typically, the 3-years old females are the most difficult group to get rebred because they are nursing their first calf (Youngquist & Threlfall, 2007). In fact, at calving, these females still have high growth requirements and are suddenly subjected to two new stresses, calving and nursing (Rice, 1986). For these three reasons, Youngquist and Threlfall (2007) referred that it is not unusual to see the pregnancy rate in this group of females to drop 5 to 10% below the herd average, while taking 10 to 14 days longer to conceive. Because of the capital invested in the replacement heifer program, it is critical that these young females be monitored and managed to ensure acceptable reproductive performance through their first two breeding seasons.

2.6. The productive life and culling rate

Lifetime production is an important measure of efficiency in beef production and is a function of fertility, maternal ability, and cow's and offspring survival (Martinez, Koch, Cundiff, Gregory & Van Vleck, 2004). Longevity of beef cows can be defined as the length of productive life from first calving to culling (Szabó & Dákay, 2009).

The culling rate is the measure percentage of dams are removed from the herd by death, slaughter or sale after calving, and may reflect a broad range of issues such as reproductive management, infectious or periparturient disease and general cattle husbandry (Gates, 2013).

According to Morrow (1980), the total culling rate is a good indication of the herd health management quality presenting a breeding goal of less than 25%. Moreover, this value should include less than 10% of involuntary culling (forced culling for infertility, mastitis and other diseases) and 15% of voluntary selective culling.

Youngquist and Threlfall (2007) in a study in Mississippi, referred that reproduction was considered the main reason for culling a beef cow, representing 60.2% of the total culling rate. Nevertheless, Noakes et al. (2009) mentioned that the overall culling figures for infertility should not exceed 5%.

The ability of cows to have a long productive life is important for commercial beef producers, since it means lower costs for the replacement program, less young cows, and thus more and heavier calves available for sale (Martinez et al., 2004). In what concerns the traits that affect productive life length, Forabosco et al. (2005) found that herd-year effects and muscularity traits were the most important factors for longevity in Chianina cows. Furthermore, Rogers, Gaskins, Johnson and MacNeil (2004) reported that cows that experienced dystocia were at greater risk of being culled than those that calved without assistance. Szabó and Dákay (2009) performed a study which showed that breed, season of first calving and calving difficulty at first calving affect longevity ($P < 0.05$), contrary to herd, age at first calving, sex of first calf and weaning weight of calves.

As mentioned before, the season affects the longevity, since cows that first calved in Spring or Summer were estimated to have longer productive lives and less risk of early culling, than those calving first in Autumn and in Winter. Szabó and Dákay (2009) stated that cows calving early in a year have a better chance to be pregnant in the main breeding season and less likely to be culled than those calving in later seasons.

Rogers et al. (2004) referred that cows experiencing dystocia have a 58% greater risk of being culled. This data are according with the results found by Szabó and Dákay (2009) who revealed that cows calving without assistance or with little assistance have a longer productive life than those needing veterinary assistance or having a stillbirth. According to Meijering (1984), increases in culling rate varied with the literature from 2% to 30%. Furthermore, the author reported a 3.5% emergency slaughter rate among Friesian heifers with dystocic calvings.

The weight of weaned calves per initial replacement female accumulated over a lifetime is a measure of the cow's contribution to the genotype of its calves for growth, its fertility (pregnancy and calving rate), its maternal ability (weaning rate), milking capacity (maternal weaning weight), and its survival (ability of the cow to delay culling or death), and has been proposed as a comprehensive measure of lifetime production (Martinez et al., 2004).

2.7. Calf analysis

The total weight of calves weaned during a cow's lifetime, is the most important output component of efficiency in the cow-calf segment of beef production. In fact, this is function of survival and reproductive performance of cows and of survival and growth rate of their offspring (Cundiff, Núnez-Dominguez, Dickerson, Gregory & Koch, 1992). Therefore, the issues of calf mortality and calf weaned and percent calf crop weaned will be discussed.

2.7.1. Calf mortality

Hubbert (1972) defined stillbirth as a full-term dead foetus. However, in order to clarify the time of death, the author specified perinatal mortality and neonatal death. Perinatal mortality include the death of fetuses and newborn calves occurring before or during birth or in the first 28 days; while neonatal death comprise the death of newborn calves within the first 28 days. Furthermore, the authors divided this period in hebdomadal (under 7 days) and post hebdomadal (8 to 28 days).

In cattle, the perinatal and early postnatal periods are characterised by high mortality rates. Bleul (2011) studied the perinatal (first 24 hours) and postnatal mortality rates during the first four months in 22 breeds and cross-breeds commonly occurring in Switzerland. The results showed an overall perinatal mortality rate of 2.4% and a postnatal mortality rate of 0.5%, 1.3% and 0.7% from days 2 to 7, 8 to 28 and 29 to 120, respectively. Several studies cited in Burns, Fordyce and Holroyd (2010) referred that total mortalities from confirmed pregnancy to weaning lie between 8% and 18%, with a perinatal mortality of 3% to 10% and postnatal mortality from 0% to 5%. Gates (2013) found that 2.47% of beef calves born in 2007 died on farm within 180 days, with an average at herd level of 2.34% (median of 0%). Although the variance between studies, according to Rice (1986) the breeding goal to calf survival at birth is 95%, the same as for nursing survival.

The most commonly reported causes of calf mortality from birth to weaning were studied by Wittum, Salman, Odde, Mortimer and King (1993). These authors conclude that dystocia (17.5%), stillbirth (12.4%), hypothermia (12.2%), diarrhoea (11.5%) and respiratory infections (7.6%) were the main factors of calf mortality on the referred period, accounting for more than 60% of all calf deaths.

Dystocia has been consistently identified as the primary cause of perinatal mortality (Bleul, 2011) and several factors were identified as predisposing causes. McDermott, Allen, Martin and Alves (1992) concluded that first parity, heavier calves, male calves, previous calving assistance, specific dam and sire breed types ($P < 0.01$) and number of calves born (single or twins) ($P < 0.05$) were statistically significant associated with calving assistance. The analysis of this problem is important, since it has many unfavourable consequences that will be discussed later (Laster, Glimp, Cundiff & Gregory, 1973).

Bleul (2011) concluded that the overall calf mortality rate was greater in dairy breeds than in beef breeds (5.0% and 4.6%, respectively; $P < 0.00001$), although the dystocia rate was lower in dairy breeds (4.7% and 5.0%, respectively; $P < 0.001$). The higher mortality during the first week in calves of beef breeds (0.7% versus 0.5%; $P < 0.0001$) may have been associated with lower immunoglobulin levels. The author referred that, although immunoglobulin concentrations were not measured in that study, beef calves that are left with their dams to nurse on their own may acquire lower immunoglobulin concentrations than dairy calves, in which colostrum intake can be controlled more easily. The difference in mortality rates after the first week is most likely related to differences in calf rearing. Dairy calves are weaned early and mingled with other calves, often from other herds, and therefore may suffer more commonly from diseases related to crowding.

Taking into account the above mentioned, the mortality of calves from birth to weaning reduces beef farm incomes and increases significantly beef production costs. It is thus necessary to integrate calf survival traits in the definition of overall breeding objective in beef cattle (Goyache et al., 2003).

2.7.2. The percent calf crop weaned

Many years ago the common goal was to produce a live calf every year, but modern livestock marketing practices demand more than just a calf every 365 days. An overall analysis of the cycle permits to conclude that cows that do not wean a live calf do not generate any revenue to offset several months of accumulated expenses, care and management (Heaton, Wilde, Nelson & ZoBell, 2013).

The percentage of calves weaned from the total cows exposed to breeding during the previous breeding season reflects three parameters that include breeding efficiency, calf survival at birth and nursing survival. Therefore, the breeding goal must take into account the values already discussed of 95% of breeding efficiency, 95% of survival at birth and 95% of nursing survival that results in 86% of calf crop.

In summary, it is possible to conclude that beef producers who apply the best reproductive management practices will have above average reproduction efficiency, improved profitability and greater sustainability (Heaton et al., 2013).

3. General considerations about dystocia

The birth of a healthy calf is the basic requirement for the economic efficiency in beef cattle production (Wehrend, Hofmann, Failing & Bostedt, 2006). However, the dystocia consequences are numerous and both dam and offspring can be affected (Noakes et al., 2009).

Parturition in cattle is a physiological process that still needs elucidation in important aspects (Meijering, 1984). It is generally accepted that the signal to initiate parturition reside in the hypothalamic-pituitary axis of the foetus that is followed by a hormone cascade, involving foetal corticosteroids, placental oestrogens and prostaglandins, and oxytocin (Meijering, 1984; Youngquist & Threlfall, 2007).

The parturition process is divided into three phases. The first stage of labour consists in the preparation of the birth canal and the foetus for expulsion (Wehren et al., 2006). It includes relaxation and dilatation of the cervix, myometrial contractions and the change of foetal disposition and ends with the rupture of the chorioallantois in the vagina (Wehren et al., 2006; Youngquist & Threlfall, 2007). The average duration of the first stage of labour is approximately 6 hours, but considerable variation among animals is observed, and it may last up to 24 hours in heifers (Youngquist & Threlfall, 2007). In the second stage of labour, the calf is visible in the *rima vulvae* and is expelled (Wehren et al., 2006). The average length of this phase is 2 to 4 hours in pluriparous cows, but can be longer in heifers (Youngquist & Threlfall, 2007). Finally, the third stage of labour is characterized by detachment and expulsion of the cotyledonary placenta. The time required for expulsion of the placenta averages 8 hours, but can range from a few minutes up to 12 hours without being considered abnormal (Youngquist & Threlfall, 2007). In normal circumstances this process should terminate without human interference being required, leaving a healthy cow with a viable calf. In reality, however, several studies referred that a significant proportion of calvings is assisted to a major degree (Meijering, 1984).

3.1. Causes, incidence and consequences

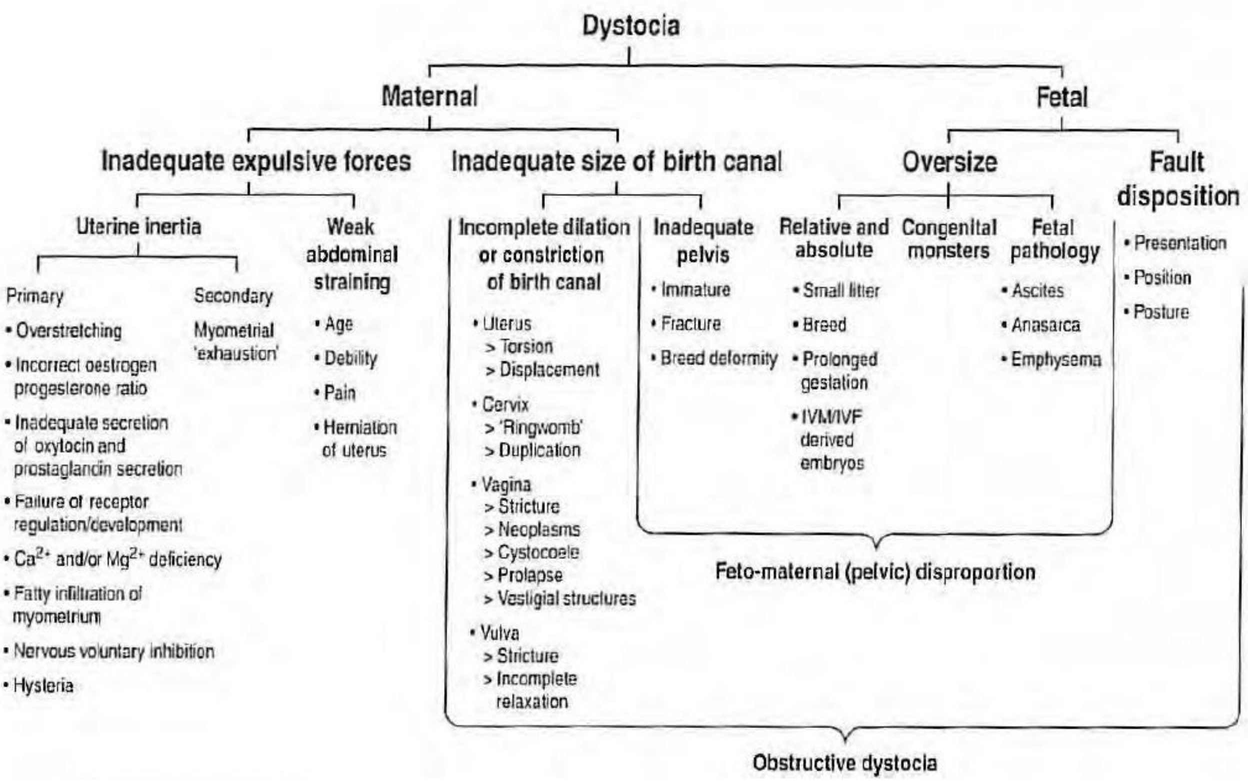
The term dystocia, from the Greek '*dys*', meaning difficult, and '*tokos*', meaning birth, was defined by Hubbert (1972) as a difficult or abnormal parturition; in contrast, the term eutocia ('*eu*', meaning normal, and '*tokos*', meaning birth) or normal calving can be defined as a spontaneous calving of normal duration (Mee, 2008b). However, many subjective case definitions and scales have been used to define these terms, and Youngquist and Threlfall (2007) mentioned that dystocia occurs when the first or second stage of labour is prolonged and assistance is required for delivery.

There are a large number of variables that influence the incidence of dystocia and that always should be considered when interpreting results. Meijering (1984) emphasized that due to different definitions of dystocia and methods of data collection, the figures stated are not easily comparable. Furthermore, Noakes et al. (2009) reinforced the importance of pondering the effect of breed, age and parity. Taking into account these aspects some values about the incidence of dystocia are then described.

Noakes et al. (2009) mentioned that dystocia is less common in dairy than in beef cattle. In dairy industries, Mee (2008b) referred that the dystocia rate varies between 2% and 7%, apart from the United States of America that presented a prevalence of 13.7%. In contrast, in beef cattle, Holland, Speer, LeFever, Taylor and Field (1993) mentioned that 81.8% of the calvings were unassisted and 18.2% were assisted in some manner. Of the assisted deliveries, mild traction, severe traction and caesarean section represented 31.8%, 44.5% and 1.3%, respectively, while 22.4% were just classified as malpresentations. Nix, Spitzer, Grimes, Burns and Plyler (1998) found 6% of dystocia rate, with 28% needing mild traction, 69% severe traction and 3% caesarean section. Furthermore, Brinks, Olson and Carroll (1973) obtained an 8.8% of dystocia in a study based on 2 971 births in Herefords.

From a clinical perspective, the aetiology of dystocia is multifaceted and includes defects in the dam or the foetus and management factors, or a combination (Youngquist & Threlfall, 2007). Noakes et al. (2009) defended that dystocia should be considered in relation to defects in the three components of the birth process: the expulsive forces, the adequacy of the birth canal and the size and disposition of the foetus. Thus, a difficult birth will occur when the expulsive forces are insufficient, when the birth canal is of inadequate size and/or shape or when the presenting diameter of the foetus is unable to pass through the normal birth canal because is too large or its disposition prevents it from doing so. Figure 1 summarizes these considerations and reviews the causes of dystocia.

Figure 1: The causes of dystocia (Noakes et al., 2009)



Based on several studies, Meijering (1984) mentioned that the fetomaternal disproportion seems to be the most single cause of dystocia, especially in first calf heifers and may be even more so in beef than in dairy breeds. The author showed the results from Sloss and Johnston (1967)[3] that present the causes of dystocia in beef herds and that obtained 46% of dystocia due to fetopelvic incompatibility.

The two primary determinants of the fetopelvic incompatibility are, in order of importance, calf birth weight and maternal pelvic size (Mee, 2008b). According to Laster et al. (1973) the dystocia rate in beef cattle increase 2.30% per 1 kg increase in birth weight.

The same study (Sloss & Johnston, 1967) referred that the faulty foetal disposition is the second cause of dystocia (26% of the total cases), being mentioned by Mee (2008b) as the first type of dystocia in pluriparous cow's. Holland et al. (1993) in a beef cattle's 21 years study (1971 to 1991) about this subject referred a 22.4% dystocia rate due to malpresentations, where the posterior dorsal position represented 72.8% of the cases, followed by unilateral carpal or shoulder flexion (11.4%) and breech (8.2%).

McDermott et al. (1992) resumed the distribution of individual dam, sire and calf factors potentially associated with dystocia. Dystocia was classified into no assistance, easy

[3] Sloss, T. & Jonhston, D. (1967). The causes and treatment of dystocia in beef cattle in Western Victoria: 2. Causes, Methods of correction and Maternal dead rates, *Australian Veterinary Journal*, 43 (1), 13-21.

assistance and hard assistance. Easy assistance required only the manual aid of one person; hard assistance with any further help. Such supplementary assistance included an additional person, any mechanical aid, a caesarean section or any other veterinary assistance. The results are presented on Table 5.

Table 3: Influence of dam, sire and calf factors potentially associated with dystocia (Adapted from McDermott et al., 1992)

Factor		Number of observations	No assistance (%)	Easy assistance (%)	Hard assistance (%)	Dystocia (%)
Parity	Primiparous	667	73.61	14.09	12.29	26.38
	Pluriparous	3702	94.46	3.78	1.76	5.54
Calf	Female	2083	93.47	4.37	2.16	6.53
	Male	2065	89.44	6.05	4.50	10.55
Calves born	Singles	4296	91.43	5.21	3.35	8.56
	Twins	73	82.19	13.70	4.11	17.81
Last calving	No assistance	3274	95.11	3.48	1.41	4.89
	Easy assistance	149	87.92	8.05	4.03	12.08
	Hard assistance	112	81.25	8.93	9.82	18.75
Dam breed	Charolais	284	90.85	5.99	3.17	9.16
	Hereford	1183	93.59	4.06	2.37	6.43
	Limousin	264	94.70	4.17	1.14	5.31
	Simmental	354	81.92	11.58	6.50	18.08
Sire breed	Charolais	896	91.07	5.58	3.35	8.93
	Hereford	1056	92.80	4.26	2.94	7.20
	Limousin	1236	92.64	4.94	2.43	7.37
	Simmental	729	85.05	8.78	6.17	14.95

The authors concluded that first parity, heavier calves, male calves, previous calving assistance, specific dam and sire breed types ($P < 0.01$) and number of calves born (single or twins) ($P < 0.05$) were statistically significantly associated with calving assistance.

Considering the higher incidence of dystocia in heifers and the major contribution of the fetopelvic disproportion in heifer dystocia cases, Meijering (1984) referred that these results could be explained by assuming that the ratio between calf size and effective pelvic dimensions is more critical in heifers than in second calf or older cows. In fact, the author mentioned that despite the birth weight increases with parity, observations in French beef breed females indicate that between the two and five years old, the pelvic inlet area of the dam may increase relatively more than the average birth weight of the calf, thus verifying a more favourable ratio between calf size and pelvic inlet dimensions with consecutive parturitions. Furthermore, Meijering (1984) underlined that higher incidence of dystocia encountered when heifers calve at a relatively young age may be due to a similar cause: poor pelvic development, not fully compensated by a smaller calf.

In what concerns to the calf sex, males presented 10.55% dystocia rate while females 6.53%. As explained before, a higher body weight is associated with an increase in the dystocia rate. The physiological basis of the weight differences between sexes at birth may be related to androgenic hormone production during the foetal period (Holland & Odde, 1992), which is consistent with the increase of 1kg to 3kg in male calves. Furthermore, this variation may be also due to a difference in size and morphology, male calves presenting larger body dimensions (Meijering, 1984; Mee, 2008b).

Considering the number of calves born, for single calvings there was 8.56% of dystocia, while in twin calvings there was 17.81%. According to the results from Echternkamp and Gregory (1999), the dystocia in twin births resulted from abnormal presentations in 78.9% cases. The authors explained that the higher incidence of this type of dystocia can be due to a relatively larger physical size/birth weight and to the effect of the location of the foetuses in the same uterine horn (60%), since both can limit each other orientation.

The relationship between the assistance in two consecutive calvings was also mentioned. The authors referred a calving assistance of 4.89%, 12.08% and 18.75% when in the last calving there was, respectively, no assistance, easy assistance or hard assistance. According to Thompson, Freeman and Berger (1981), there is a large genetic correlation between dystocia in first and later parities (0.84), indicating the major influence of the same genes affecting dystocia in all parities. In fact, the pelvic inlet dimensions of the dam and the dam's influence in the birth weight are effects that contribute to dystocia (Meijering, 1984).

The dam and sire breed analysis' showed that the rate of dystocia varies with the breed. In this study, the Limousin dam breed showed a calving assistance of 5.31% which contrasts with the 18.08% dystocia rate found in the Simmental dam breed. In the sire breed, the Hereford and Limousine showed the lower values (7.20% and 7.37%, respectively), while the Simmental sire breed presented the highest dystocia rate (14.95%).

Regarding the consequences of dystocia, it is necessary to considerer the dam and the offspring. On the dam's side, it was referred that dystocia increases the mortality and culling rate, while reducing the productivity and the subsequent fertility and increasing the chance of sterility. Furthermore, it was also mentioned that it could increase the likelihood of puerperal disease. On the offspring's side, it was reported that a difficult parturition increases stillbirth rate, mortality and neonatal morbidity (Noakes et al., 2009). These consequences will be discussed in the next chapters.

3.2. The treatment of a dystocia case

Each dystocia case is a clinical problem that may be solved if a correct procedure is followed (Noakes et al., 2009). Therefore, it is necessary to recognize when deliveries may need assistance.

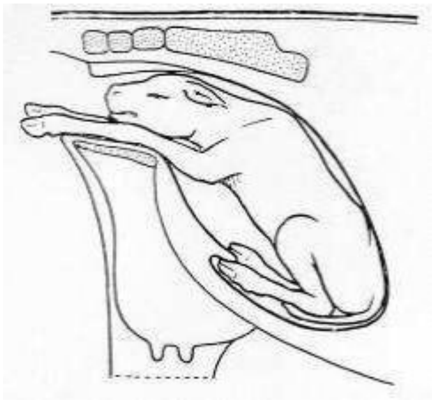
According to Jackson (2004) and Mortimer (undated), specific signs of dystocia during the first stage of labour include a prolonged, non-progressive phase (over than 8 hours), and an abnormal posture of the cow (that can be a sign of uterine torsion). Furthermore, during the second stage, failure of the calf to be delivered within 2 hours of the amnion appearing at the vulva, a vigorously straining period of 30 minutes without the appearance of the calf and a resting period of over 15 to 20 minutes after a period of progress are signs of dystocia. In fact, the resting period should not exceed 5 to 10 minutes, unless fatigue and/or uterine inertia are involved. Moreover, the obvious malpresentions, the signs of excessive fatigue and stress of the cow (severe bleeding from the rectum) or calf (severe congestion of the head, tongue and forelegs) or the appearance of detached chorioallantois, foetal meconium or blood-stained amniotic fluid at the vulva should be also considered.

The approach to an obstetric case is initiated by a review of the history: previous occurrences in the herd, information about the animal, gestation length and case progress (Youngquist & Threlfall, 2007; Noakes et al., 2009). In what concerns to the last point, the obstetrician should have information about the duration of labour and progress of calving: rupture of the foetal membranes and time elapsed, character of expulsive efforts and if any parts of the foetus already appeared at the vulva (Jackson, 2004; Youngquist & Threlfall, 2007; Noakes et al., 2009). It is also important to determine if the patient has been examined or if it has been made any attempts to deliver the calf and how (Youngquist & Threlfall, 2007; Noakes et al., 2009).

Then, the clinician should perform a physical examination to observe the general condition of the patient and identify abnormalities that may potentially influence the selection of a method to relieve the dystocia or have an impact on the prognosis (Youngquist & Threlfall, 2007). Attention should be paid to expected prodromal changes of the udder, pelvic ligaments, vulva and surrounding area. The character of any discharge from the birth canal or any exposed portion of the foetus or membranes should be noted (Youngquist & Threlfall, 2007).

The birth canal and status of the foetus are evaluated during the vaginal examination. Therefore, the clinician should assess the dilation and integrity of the birth canal, including the state of natural lubrication or dryness, abnormal structures or the presence of a uterine torsion (Jackson, 2004). In what concerns the foetus, the operator should determine, as accurately as possible, its disposition, which comprises presentation, position and posture, and if it is alive or dead (Jackson, 2004; Youngquist & Threlfall, 2007).

Figure 2: The foetal eutocic disposition (Meijer, 2005)



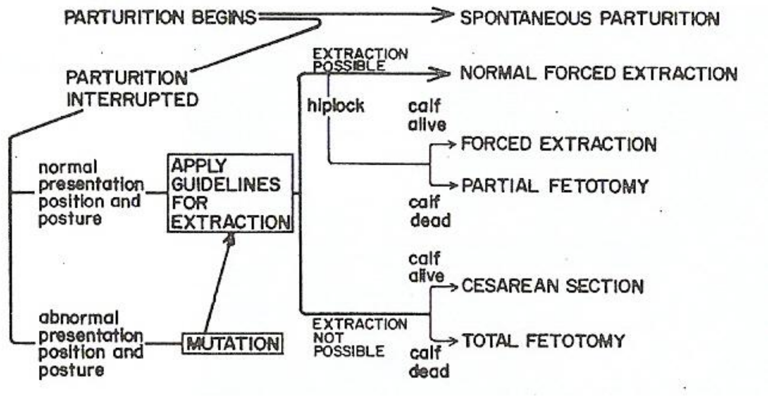
According to Noakes et al. (2009), presentation means the relationship between the longitudinal axis of the foetus at the maternal birth canal; position indicates the surface of the maternal birth canal to which the foetal column is applied; and posture refers to the disposition of the movable appendages of the foetus. So, in an eutocic disposition, the calf should be in anterior longitudinal presentation, dorsal position and in a posture in which the extended head and neck are resting on the extended forelimbs (Jackson, 2004), as shown in Figure 2.

The assessment of the presented foetus viability can be done by attempting to elicit reflexes such as the interdigital claw reflex, eye reflex, suckling reflex or anal reflex or analyse the foetal movement (Jackson, 2004; Youngquist & Threlfall, 2007; Noakes et al., 2009). If the foetal reflexes are ambiguous or absent the obstetrician should examine the foetal heartbeat (the normal intrauterine heart rate is 70 to 120 beats per minute) or umbilical cord pulse. It is also important to notice that the clinician should observe other signals, for example: severe congestion of the head, tongue and forelegs that are the result of prolonged impaction of the foetus in the birth canal; and exaggerated movements of the foetus that may be agonal, indicative of impeding death. Furthermore, although cattle generally are considered to be uniparous, twins and greater multiples are not rare. Thus, during the vaginal examination, the number of foetuses must be determined and their appendages identified (Youngquist & Threlfall, 2007).

After the status of the foetus has been analysed, the operator must estimate the size of the foetus relative to the size of the soft tissue and bony components of the palpable parts of the birth canal, in order to understand the likelihood of the foetus to passing through it (Jackson, 2004; Youngquist & Threlfall, 2007).

On completion of the examination and assessment of the condition of the dam, birth canal and foetus, the clinician should then formulate a plan for resolution. The available options to the treatment of a dystocia case are described in Figure 3 and include the mutation of abnormal presentation, position, or posture; forced extraction; fetotomy; and caesarean section. Euthanasia may be indicated in situations in which the value of the animal is limited and the prognosis is very poor (Youngquist & Threlfall, 2007).

Figure 3: Flow pattern for parturition (Schuijt & Ball, 1980)



As can be seen in the figure above, the resolution plan takes into account the normal or abnormal disposition of the foetus, the comparison size of the foetus and birth canal and if it is alive or not. According to Schuijt and Ball (1986), the calf extraction in anterior presentation is possible when, in the standing cow, with the head completely in the pelvic cavity and the pull of one person during straining, a hand can be placed between the cranium and sacrum. Moreover, both points of the shoulder should be 10 cm or less cranial to the pelvic inlet. In the recumbent animal, the authors mentioned that it must be possible to feel both points of the shoulder 5 cm or less cranial to the pelvic inlet. Nevertheless, Schuijt and Ball (1986) adverted that when a great amount of force is required to deliver the head, extraction is not the choice method, because the foetus is probably oversized. According to Newman and Anderson (2005), in beef breeds, there should be enough space in the pelvic canal for the calf's head and legs with clearance to sweep an arm around the calf's shoulders. Considering the guidelines for extraction when the calf is in posterior presentation, Schuijt and Ball (1980) mentioned that it must be possible to expose both hocks at the vulvar area.

There are also other variables that need to be balanced in a dystocia case treatment. As explained by Youngquist and Threlfall (2007), when considering the extraction, it is necessary to understand that it results in foetal respiratory acidosis, and the operator must determine if the risks of harming the dam and the foetus during extraction are justified. Furthermore, the value of the dam and the potential value of the offspring, the cost of the procedure and aftercare and the life prognosis of the dam and the foetus, including the dam's reproductive performance should also be pondered. The authors remarked that the facilities and assistance available, as well as the personal preferences of the animal's owner and the clinician influence the decision.

3.2.1. The mutation of abnormal presentation, position and posture

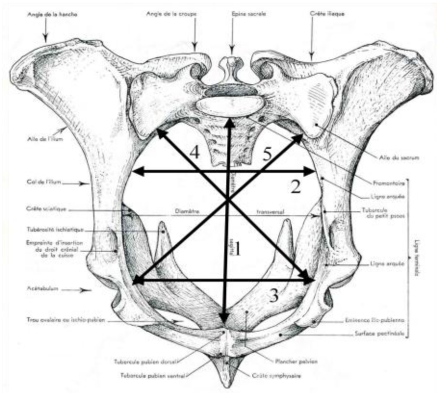
As it was mentioned before, the disposition of the foetus is evaluated based on three coordinates: presentation, position and posture. In order to correct dystocia cases, Youngquist and Threlfall (2007) explained that mutation is the process by which a foetus is restored to normal presentation, position, and posture by repulsion, rotation, version or extension.

Schuijt and Ball (1980) presented the guidelines for attempted mutation, where the authors recommended that when the foetus is alive, abnormalities in foetal disposition should be diagnosed and corrected before traction. In cases when the foetus is dead and the reposition is difficult or dangerous, partial fetotomy should be performed. Furthermore, the authors advised that if there is no progress within a maximum of 30 minutes, caesarean section or fetotomy is indicated.

The repulsion (or retropulsion) refers to the movement of the foetus from the vagina (and the bony pelvic canal) into the uterus with the aim of getting more space available to rectify disposition defects (Youngquist & Threlfall, 2007; Noakes et al., 2009).

Rotation is defined as turning the foetus on its longitudinal axis, being possible to change from a dorsoilial or dorsopubic position to a dorsosacral position (Youngquist & Threlfall, 2007; Noakes et al., 2009). Furthermore, the partial rotation is an essential component of the routine vaginal delivery technique, since the rotation of the calf allows its widest portion, the hips, to come through the greatest diameter of the pelvic inlet (Schuijt & Ball, 1986; Youngquist & Threlfall, 2007). As explained by Schuijt and Ball (1986), the maternal pelvic inlet has a wider dorsopubic than bisiliac diameter, while the hips of the foetus are larger between its greater trochanters. Therefore, the 60º to 90º degrees rotation of the foetus into the dorsoilial position permits to take advantage of the correspondence between the greater diameters (Figure 4).

Figure 4: Anterior view of the pelvis of the cow: the 5 diameters from the anterior view (adapted from Hanzen, 2009).



1: Sacropubic diameter. 2: Superior bisiliac diameter. 3: Inferior bisiliac diameter. 4: Right sacroiliac diameter. 5: Left sacroiliac diameter

Another possible obstetric manoeuvre is the version that is defined as the alteration of transverse or vertical to longitudinal presentation (Noakes et al., 2009).

Finally Noakes et al. (2009) mentioned the extension that refers to the extension of flexed joints when postural defects are presented.

3.2.2. Delivery by extraction

It has been estimated that an average force of 70kg is required to deliver a bovine foetus, and that 40% of this pressure is supplied by the uterine contractions and 60% by the abdominal press (Youngquist & Threlfall, 2007). However, when dystocia occurs it may be necessary to perform traction which, according to Noakes et al. (2009), means the application of force to the presenting parts of the foetus in order to supplement, or in some cases replace, the maternal forces.

A very important consideration is the magnitude of the supplementary force that may be used, since excessive force inappropriately applied can cause severe trauma to dam and offspring (Noakes et al., 2009). Youngquist and Threlfall (2007) referred that, ideally, the force applied for traction should be limited to less than the force that can be applied by one person. The authors explained that this is commonly possible in cases of foetal normal disposition and when the correct delivery techniques and guidelines for extraction have been met. Moreover, it has been recommended that the force of traction should not exceed 70kg in Holsteins and 35kg in Jerseys or two men (Mee, 2004) or one man per limb (Mortimer, undated). According to Noakes et al. (2009) the well-coordinated pull of four average persons should be the limit.

In what concerns the mechanical foetal extractors, Jackson (2004) and Youngquist and Threlfall (2007) considered that these devices are useful when minimal human assistance is available. In fact, Noakes et al. (2009) mentioned a study about the magnitude of the forces used to apply traction[4], where it was concluded that a calving jack could exercise a tractive effort of 400kg, a value much higher than the 75kg of traction by one person or 115kg by two persons.

As it was above mentioned, dystocia can have repercussions to the dam and offspring. In what concerns the calf, it is referred that dystocia is a potential source of trauma, especially when excessive force is applied during the delivery process. Furthermore, prolonged hypoxia and significant acidosis are common problems in calves that experience prolonged or severe dystocia, which can be immediately fatal or reduce long-term survival (Lombard, Garry, Tomlinson & Garber, 2007). Murray and Leslie (2013) explained that as a consequence of these problems, the calf may be unwilling or unable to get up and suckle the colostrum in a timely manner. The early colostrum intake improves passive immunoglobulin transfer, energy uptake and thermoregulation. Therefore, not receiving enough colostrum shortly after birth may affect a calf's long-term health status and put it at greater risk of disease and mortality. In addition, the other mechanisms of heat production that include the metabolism of brown adipose tissue, shivering and physical activity may be also compromised in calves with low vitality.

With respect to the trauma, as a consequence of excessive force during the delivery, the calf can present injuries in the vertebral column (that include vertebral fracture, myelomalacia, spinal cord compression or severed spinal cord) and ribs, limbs and mandibula fractures (Youngquist & Threlfall, 2007; Murray & Leslie, 2013). Furthermore, Youngquist and Threlfall (2007) referred that calves delivered in cranial presentation may also suffer trauma associated with failure of the stifle joints to enter the pelvic canal, which can cause damage to the femoral nerve, with subsequent neurogenic atrophy of the hind limb muscles. If the injuries are not immediately fatal, calves are usually weak and with lack of mobility, which interferes with the natural interactions and behaviours that should occur with the dam (Murray & Leslie, 2013).

As referred above, another consequence of dystocia is the hypoxia and acidosis. Due to the rupture of the foetal membranes and the uterine contractions that occur during parturition, it is possible to observe disturbances in the uterine-placental circulation, that promotes a more or less severe hypoxia and so acidosis (Szenci, 2003). Furthermore, Murray and Leslie (2013) referred that the hypoxia and acidosis can also occur as a consequence of premature rupture of

[4] Hindson, J. (1978). Quantification of obstetric traction. *Veterinary Record*, 102, 327-332.

the umbilical vessels in prolonged dystocia or forced extraction. Consequently calf survival is affected by the duration of calving and the duration and force of assistance (Mee, 2008a).

When the foetus oxygen supply from the placenta is interrupted before the calf being able to regulate its own respiration, a rapid development of asphyxia and respiratory acidosis occurs. If the hypoxia is severe enough, foetal tissues will derive energy from anaerobic glycolysis, with subsequent production of lactic acid and metabolic acidosis, which can compromise the newborn survival. Furthermore, effects of asphyxia can result in decreased blood flow, with possible hepatic necrosis, liver dysfunction and renal tubular acidosis (Murray & Leslie, 2013). As blood pH drops, vitality is reduced first, subsequently vital organs are damaged and ultimately the foetus dies (Meijering, 1984). Therefore, hypoxia and acidosis can play an important role in calf's ability to maintain homeostasis and thermoregulation with a subsequent greater risk of mortality.

Considering the referred consequences, Noakes et al. (2009) explained that dystocia could increase stillbirth rate, mortality and neonatal morbidity. Laster and Gregory (1973), studying the dead at birth or within 24 hours after birth, found a calf mortality of 19.2% when a calf puller was used versus 5.0% in non-assisted parturitions. The authors explained that this difference was attributed to delay in receiving assistance or to the difficulty and time required to remove the calf. In comparison, Nix et al. (1998) referred a calf mortality rate of 20.93% and 30.19% in calvings with mild and heavy traction, respectively, and 2.75% when there was no assistance. Moreover, Patterson, Bellows, Burfening and Carr (1987) mentioned that calf death due to dystocia was the single largest loss category through the first 96 hours postpartum and that the majority loss attributed to dystocia occurred within the first 24 hours postpartum accounting for 40% of total calf deaths.

In what concerns the dam, the excessive traction during delivery can cause several injuries, including contusions and lacerations of the birth canal and neighbouring structures, maternal obstetric paralysis and pelvic or limb fractures (Jackson, 2004; Youngquist & Threlfall, 2007; Noakes et al., 2009).

Regarding the trauma of the birth canal soft tissues, Haibel (1986) explained that there is a high probability of occurrence, not only due to fetopelvic incompatibility with normal presentation, but also as a consequence of the mere fact that the calf is aided with traction rather than pushed out, which elongates and constricts the vagina. Furthermore, in assisted delivery, it is possible that dilation of the cervix, vagina and vulva caused is not completed.

Although any part of the birth canal may suffer contusion during foetus forcible extraction, Noakes et al. (2009) explained that cervix and vulva are more likely to be lacerated than the dilatable vagina. In beef breeds, however, the retroperitoneal fat surrounding the vagina of heifers make such animals particularly prone to vaginal contusion when the foetus is oversized (Noakes et al, 2009).

In order to prevent vulvar and perineal lacerations and increase the diameter of the vulva, it is possible to perform an episiotomy (Noakes et al., 2009). This procedure is most commonly observed during the management of dystocia when the vulva has not fully dilated or there is a fetomaternal disproportion and typically in heifers (Youngquist & Threlfall, 2007).

In what concerns the uterine lacerations, they may have resulted from mutation of limbs with inadequate uterine relaxation or lubrication or from injudicious use of fetotomy instruments (Haibel, 1986). In addition, uterus rupture can occur due to faulty obstetric technique (the most frequent cause), being also possible when a severe uterine distension occurs, for example, twins in one uterine horn, hidroallantois or excessive foetal size, or a long-standing dystocia with a dry foetus and contracted uterus (Haibel, 1986; Noakes et al., 2009).

The management and prognosis for birth canal trauma depends on location, severity and existence of sepsis, being possible to have a favourable outcome or result in the cow's death (Haibel, 1986).

Maternal obstetric paralysis can occur as a result of damage to the nerves, including the obturador nerve and the sixth lumbar nerve root (Divers & Peek, 2008). The obturator nerves pass from the lumbosacral plexus along the medial surface of the ilia and through the obturator foramen on the pelvic floor (Jackson, 2004). In addition, the sixth lumbar spinal nerve passes ventral to the prominent ridge of the sacrum (Divers & Peek, 2008). So, when an oversized foetus is forcibly drawn into the maternal pelvis, the foetal pressure on the cow nerves' can cause damage, leading to paralysis. This type of injury is particularly likely when the foetus becomes impacted in a state of hiplock (Noakes et al., 2009).

The sixth lumbar spinal nerve contributes to the sciatic nerve branches as well as to the tibial and peroneal nerve (Divers & Peek, 2008). In cases where the cow has been in prolonged lateral recumbency during calving or dystocia, pressure can cause damage to the peroneal nerve. Less commonly, the whole sciatic nerve can be affected.

All of these potential complications negate any short-term benefit that may be gained from succumbing to the temptation of using excessive traction to perform a delivery (Youngquist & Threlfall, 2007). Therefore, Noakes et al. (2009) recommended that if after 5 minutes of judicious traction no progress is made, the veterinary surgeon must resort to a caesarean section if the calf is alive or dead or fetotomy if the calf is dead.

3.2.3. The caesarean section

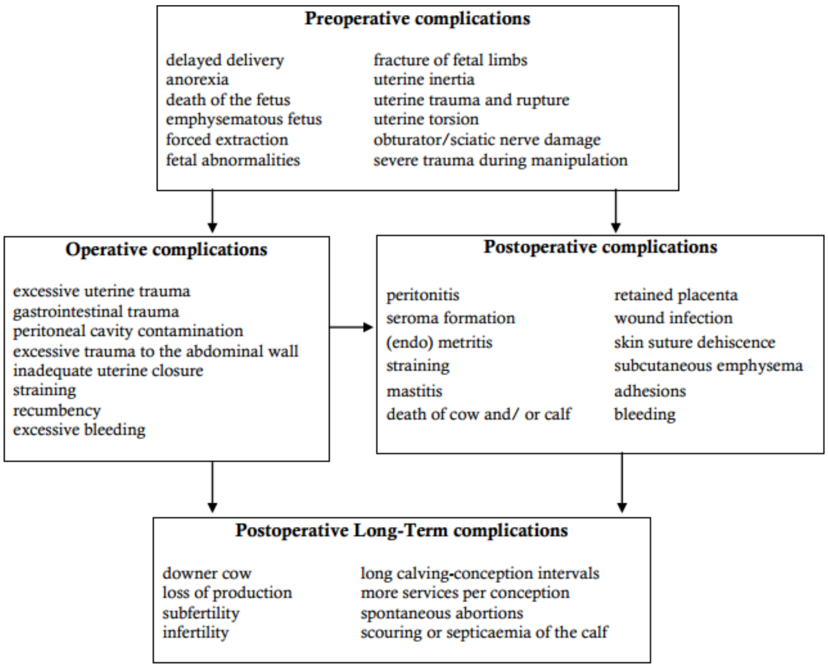
The basic goals of performing a caesarean section are the preservation of the dam and the calf and the future reproductive efficiency of the dam (Newman & Anderson, 2005). However, there are a number of variables that determine the procedure success. Newman (2008) mentioned that the health status of the cow and calf at the time of surgery is recognized as the most important determinant of outcome.

Considering that there are different expected results and complications, it is possible to categorize this procedure as: elective, emergency (non emphysematous) or emphysematous. So, cases of elective caesarean section are less likely to encounter intraoperative and postpartum complications (Newman & Anderson, 2005; Newman, 2008).

In what concerns the surgical approach, Schultz, Tyler, Moll and Constantinescu (2008) explained that it is possible to perform a standing or recumbent paralumbar celiotomy (on the left or right side of the abdomen), a recumbent ventral midline celiotomy, a ventrolateral celiotomy or a standing left oblique celiotomy. Each procedure has its own advantages and disadvantages, being that the selection of an approach is based in several questions, which include the type of dystocia, the cow's condition, the environmental conditions, the availability of assistance and the surgeon's preference (Schultz et al., 2008).

Every caesarean section, even the routine elective caesarean section, it a major abdominal surgery performed in a contaminated environment. So, although performed under surgical sterility, it cannot be considered without any difficulties and/or complications before, during and after the operation (Kolkman et al., 2010). Kolkman (2010) resumed these problems, as it is possible to see in the Figure 5.

Figure 5: Complications of the caesarean section (Kolkman, 2010)



Kolkman et al. (2010) performed a study about pre-operative and operative difficulties in bovine caesarean section in Belgium. The authors concluded that performing a caesarean section at an early stage during parturition significantly reduces the odds of encountering problems before and during the surgery. Despite this, they reinforced that females that have been previously submitted to a caesarean section presented an increased risk of mild and severe difficulties.

At this point, it is however important to reinforce that the selection of the double-muscled phenotype in the Belgian Blue cattle led to a large foetal size, high birth weight and conformation or both which, as explained by Kolkman (2010), was unintentionally accompanied by a decrease in the inner pelvic dimensions and a small variation in the maternal pelvic size, thus creating a high dystocia incidence. Nevertheless, the high price of the calf (500€ to 700€) versus a low price of the caesarean section (70€ to 85€), combined with the price of even losing a valuable cow (2.0€/kg to 2.5€/kg) and the market pressures, have made that the caesarean section became standardized in Belgium in order to circumvent this problem (Hanset, 1998; Lips, Tavernier, Decuypere & Van Outryve, 2001).

Considering the postoperative problems, Hanzen, Théron and Detilleux (2011), studying the bovine caesarean section in Europe, concluded that 5.3% cases were accompanied by complications. The main causes of these problems were: retained foetal membranes (31.3%), cutaneous abscesses (30.1%) and peritonitis (14.1%).

In what concerns the retained foetal membranes, in dairy cattle, Joosten, Van Eldik, Elving and Van Der Mey (1987) reported 5.0% of retained foetal membranes in calvings with no assistance, in comparison with 6.3% and 13.3% when there was an easy and hard pull, 13.6% following caesarean section and 26.2% after fetotomy. However, in the Belgian Blue beef cattle, Hanzen et al. (1994) found a retained placenta rate between 4% and 5%, emphasizing that it appears that caesarean section does not induce a higher frequency of retained placenta than normal calving. As explained by Beagley, Whitman, Baptiste and Scherzer (2010), the pathophysiology of this problem is related to the trauma of the uterus that occurs in all these cases and that can result in oedema of the chorionic villi and increase in heparin release from mast cells, which inhibits collagenases, both contributing to retained foetal membranes. In addition, the authors explained that dystocia and uterine trauma has been associated with uterine atony, which could inhibit the expulsion of membranes leading to retention.

Mijten, Van den Bogaard, Hanzen and De Kruif (1997) referred that complications after caesarean section delivery in cattle are mainly result of infections. According to the authors, the bacteria responsible for these infections can be of exogenous or endogenous origin. Exogenous contamination gains access to the abdominal cavity at the surgical incision during operation. In this case, the bacteria are mostly saprophytes and are present in low numbers. In contrast, a more serious contamination is of endogenous origin. Mijten et al. (1997) explained that the foetal fluids are contaminated with the endogenous vaginal flora and so, during the operation, they may have access to the wound and the abdominal cavity.

The wound infection is also a sequel of the caesarean section. Seger, Grunert and Ahlers, (1994) studied the complications causes of abdominal incision healing after caesarean section. The authors categorized this problem as mild, moderate or severe, reporting 6.7%, 6.3% and 9.1% of wound complications, respectively. Furthermore, Seger et al. (1994) explained that several factors negatively influence the healing process: duration of parturition, macroscopic condition of the allantoic and/or amniotic fluid and degree of the exposure of the uterus outside the laparotomy wound.

In what concerns to peritonitis, it is important to understand that it only occurs when the clearance capacity of the abdomen is exceeded or when the uterine fluid is too contaminated, leading to the appearance of clinical signs (Kolkman, 2010).

Another referred complication during the postoperative period is the mortality of the dam, that, according to Hanzen et al. (2011), occurs in 2.2% of the cases. One of the conditions that influence cow survival is calf viability. Bouchard, Daignault, Bélanger and Couture (1994), in a study in dairy cattle, found that cow survival decreased from 86% with a live calf to 79% with a dead calf, diminishing to 33% in cases where the foetus was emphysematous. Furthermore, Kolkman (2010) referred that mortality rate was affected by recumbency during caesarean section and the surgery duration. Kolkman et al. (2010) reported a 2.3% recumbency rate (2.2% in Belgian Blue and 4.6% in other breeds), while Hoeben, Mijten and De Kruif (1997) found 14.8%. The latter authors also referred that dairy cows became recumbent more often than did beef cows (17.8% versus 10.4%), and heifers more often than multiparous cows (17.0% versus 12.0%). Newman and Anderson (2005) observed that cows that became recumbent during the surgery are more likely to develop peritonitis and experienced greater postoperative mortality. In what concerns to the duration of surgery, Kolkman (2010) referred that an increased surgical duration is a negative factor in surgical mortality.

As can be seen in Figure 5, calf's mortality is also one of the postoperative complications to consider. According to Kolkman (2010), a large proportion in calf survival rate after caesarean section is due to the early intervention and thus the relatively short duration of parturition. So, Laster and Gregory (1973) found 23.9% of calf mortality in comparison with Nix et al. (1997) that reported 50.0%, while Lyons, Karvountzis and Knight-Jones (2013) found 33.3% of perinatal mortality in elective caesarean sections and 66.7% in non-elective caesarean section. In Belgium, Michaux and Leroy (1997) recorded 40 125 calvings of double-muscled Belgian Blue cows and found a mortality rate at 48 hours postpartum of 2.0% in caesarean section cases', in comparison with 5.6% when there was no assistance and 3.6% and 7.9% in cases of slight assistance and traction, respectively.

In what concerns the perinatal mortality, Mee (2008a) referred that, after a caesarean section, calves may suffer from respiratory distress syndrome, a condition in neonatal calves in which it is possible to observe an insufficient oxygen uptake and increased retention of carbon dioxide that results in respiratory acidosis (Bleul, 2009). Although more associated with premature calves that present surfactant deficiency, it can also occur after a caesarean section (Bleul, 2009).

The pathophysiology of this syndrome is related to the fact that passage through the birth canal triggers foetal catecholamine release, which inhibits lung liquid secretion and stimulates its absorption, promotes surfactant secretion and increases lung compliance and foetal oxygenation (Mee, 2008a).

The catecholamine release, when there is not yet a splanchnic innervation of the adrenal medulla occurs by a direct, non-neuronal response that results in noradrenaline secretion. Later, when the splanchnic innervation has been established, which in calves occur postnatally, adrenaline is the predominant adrenal amine (Padbury, 1989).

The majority of mammalian species have also extramedullary chromaffin tissue as a source of circulating cathecolamine. This extramedullary tissue, also known as para-aortic tissue or organs of Zuckerkandl is well developed in the foetal and neonatal life, undergoing involution in older animals (Padbury, 1989).

In what concerns the catecholamine release at birth, Padbury, Polk, Newnham and Lam (1985) and Padbury (1989) explained that, although the factors that regulate the sympathoadrenal activity at birth are not completely understood, it probably represents an integrated response to compression, umbilical cord cutting, mild asphyxia, vestibular and tactile stimulation and hypothermia.

According to McGeady, Quinn, FitzPatrick and Ryan (2006) the lung development in human and domestic animals include five stages: the embryonic stage, the pseudo-glandular stage, the canalicular stage, the terminal sac stage and the alveolar stage. Between the 6 and 8 months of the foetal development, concretely in the terminal sac stage, a large number of terminal sacs, corresponding to the primitive alveoli, are formed from the respiratory bronchioles. This structures are initially lined by cuboidal epithelial cells which then differentiated into two cell types: the type I alveolar cells, which are involved in the post-natal gaseous exchange, and the type II alveolar cells, that secrete surfactant forming a phospholipid layer that covers the luminal surface of the alveoli. McGeady et al. (2006) explained that the production of this substance is twofold: reduce the surface tension preventing the alveolar walls adhesion during the development, and facilitate the expansion of the alveoli during inspiration and prevents their collapse during expiration. In the final stage of pulmonary development, the alveolar stage, there is also an increase in the type II cells number, resulting in enhanced secretion of surfactant. Moreover, during parturition, there is an increase in the surfactant secretion in response to the catecholamine release (Mee, 2008a). This event it is mediated by the release of disaturated phosphatidylcholine, the major phospholipid component of the surfactant and the one most responsible for lowering surface tension, in response to the β-adrenergic stimulation (Dobbs & Mason, 1979; Scarim, Ghanbari, Taylor & Menon, 1989).

During the foetal development the lungs are filled with fluid, which, in infants, is characterized by a high chloride concentration, few proteins, some mucus from the bronchial glands and surfactant from the alveolar epithelial cells type II. Furthermore, movements of muscles associated with respiration begin prior to birth and can cause aspiration of a small amount of amniotic fluid (Sadler, 2012). The presence of fluid is considered to be an important stimulus for expansion of the alveoli as a reduced fluid volume is associated with pulmonary hypoplasia. Moreover, the respiratory movements are considered essential for post-natal survival, as they prepare the respiratory muscles for breathing at birth and also promote pulmonary development (McGeady et al., 2006).

During the transition to postnatal air breathing, additionally from the surfactant secretion into the alveolar space, it is necessary to clear the lung fluid from the alveoli and pulmonary intersticium (Padbury, 1989). Therefore, shortly before birth, foetal lung fluid production ceases, possibly due to catecholamine-mediated effects, and so the balance between the plasma and the lung fluid is the protein oncotic pressure, that is higher in the plasma, causing an absorption of this fluid (Nathanielsz, 1984). Another described mechanism is the compression of the thoracic cage that occurs during parturition and that results in the elimination of lung fluid (Faxelius, Hagnevik, Lagercrantz, Lundell & Irestedt, 1983). Furthermore, the lung expansion at birth lowers the interstitial hydrostatic pressure and an acute epithelial permeability permits diffusion through its pores (Nathanielsz, 1984).

The rate at which lung areas inflate and deflate is determined by the airway resistance and lung compliance, which can be defined as the change in lung volume per unit pressure change (MacDonald, Mullet & Seshia, 2005). According to Battisti, Bertrand, Rouatbi and Escandar, (2012) at parturition and during the first week of life an increase in the lung compliance is observed as a consequence of several factors that include: the progressive disappearance of the interstitial fluid and the intervention of endogenous surfactant effect on alveolar surface.

In what concerns to the first breath, Bleul (2009) explained that it requires a great deal of energy in order to overcome the elasticity of the lungs (lung compliance), surface tension and high viscosity of the pulmonary fluid, the latter representing the greatest resistance. The incoming air just fills a few areas of lung, while others remain collapsed and so, with subsequent breaths and in consequence of the reduced alveolar surface, air is retained in the lungs after expiration, thereby opening more and more areas.

Wang, Zhang and Zhao (1999), in human medicine, showed that the levels of plasma catecholamines in patients who had elective caesarean section were significantly lower than those who had vaginal delivery and emergency caesarean section ($P < 0.01$). Furthermore, the authors found that catecholamines levels in the vaginal delivery group were significantly higher than those in the caesarean section group ($P < 0.01$), results that are according to the findings of Ronca, Abel, Ronan, Renner and Alberts (2006) in newborn rats. Considering these issues, the higher incidence of respiratory distress syndrome in infants delivered by caesarean section can be explained by the lack of compression of the thoracic cage that occurs in the vaginal delivery and the lower catecholamine release that is influenced by labour and delivery (Faxelius et al., 1983).

3.2.3. The fetotomy

As observed before, the fetotomy is another possibility for dystocia treatment. By definition, this procedure consists in the section of a foetus into two or more parts within the uterus and vagina, with the purpose of reducing its size such that delivery through the birth canal becomes possible (Noakes et al., 2009). In order to achieve this goal, it is possible to perform a complete fetotomy, when the whole foetus is divided into smaller pieces, or partial fetotomy, when a small part of the foetus is cut and removed (Jackson, 2004). However, Momont (2005) explained that for most practitioners in the field, caesarean section may be preferable to performing a complete fetotomy.

The decision guidelines above mentioned (see Figure 3) elucidated when fetotomy is indicated. However, Youngquist and Threlfall (2007) reinforced that this procedure should not be used as a last resort, after the application of excessive traction, when the dam and the operator are exhausted and the birth canal as been traumatized. In general, fetotomy, that should be considered only when the foetus is known to be dead, is useful in cases of foetal maldisposition that cannot be corrected by manipulative means, cases of incomplete cervical dilation, or to deliver a pathologically enlarged foetus (emphysematous calf) or monster (such as *schistosomus reflexus*). Furthermore, it can be used when fetopelvic disproportion is observed or when the foetus becomes stuck during delivery (e.g. hiplock) (Jackson, 2004; Youngquist & Threlfall, 2007; Noakes, 2009).

There are two basic types of fetotomy: subcutaneous fetotomy and percutaneous fetotomy. The subcutaneous fetotomy is a procedure performed with chisels and hooks, where the foetal parts are removed while leaving the foetal skin to protect the genital tract and serve as points of traction. In contrast, percutaneous fetotomy is performed with a fetotome and wire saw, with sections of the foetus progressively removed (Youngquist & Threlfall, 2007). Although this technique is the most commonly employed, damage to the uterus and birth canal during cutting and manipulation of the foetus is a potential risk (Noakes et al., 2009)

Wehrend, Reinle, Herfen and Bostedt (2002) performed a retrospective study about fetotomy in cattle while evaluating 131 operations. According to the authors, the main cause of dystocia that may lead to performing this procedure was the incorrect disposition of the dead foetus (38.9%), followed by the fetomaternal disproportion (25.2%).

In what concerns the complications of this procedure, Wehrend et al. (2002) referred that irregularities in the puerperal period occur in 67.2% of the cases, being the most common complication retained foetal membranes (37.4% of the total cases). Furthermore, the authors reported 6.9% cow mortality.

With respect to the most important factors for the postoperative prognosis, Wehrend et al. (2002) referred the time of labour and trauma to the soft birth canal. In fact, in this study, the authors observed that cows that exhibited postoperative complications were, on average, 19.2 hours in labour prior to parturition, in contrast with 8.4 hours in animals that had a normal postpartum period.

4. The dystocia as a cause of decreased reproductive performance

As explained in the first chapter, in beef herds, the maximum reproductive efficiency, which is most often achieved when replacement heifers calve by 24 months of age without any complications and deliver a live calf every 12 months thereafter until reaching the economically optimal time for culling, is paramount in determining profitability (Ball & Peters, 2004; Gates, 2013). Consequently, the frequency and the repercussions of the calving difficulty are limiting factors in the productivity (Ménissier, Sapa, & Poivey, 1992). Considering this subject, Ducrot, Cimarosti, Bugnard and Luquet (1994) observed that the risk of infertility seems to increase with any assistance during calving. The authors reported that the infertility risk increased with the level of calving assistance, being particularly high when there was a caesarean section (odds ratio of 6).

In what concerns the calving interval, the Chambres d'Agriculture des Pays de la Loire (2010) and Ducrot et al. (1994) found that the average calving interval was increased with the level of calving assistance. The first one, considering the calving difficult, found an increase in the calving interval between the first and second calving in four different breeds. The authors reported that, on average, the increase in the calving interval was about 6 days in cases of hard assistance and 31 days when a caesarean section was performed in comparison to calvings with no or easy assistance. Furthermore, in a survey carried out in France taking into account data from 3 583 cows, Ducrot et al. (1994) also found that the average calving interval was 369 days when there was no assistance, increasing to 373 days when there was easy assistance, 379 days when there was assistance with a calf puller, 385 days in cases of forcible extractions and 405 and 399 days when a caesarean section was performed with or without forcible extraction attempt, respectively.

Laster et al. (1973), considering the 1 889 cows information that were bred by artificial insemination (AI) for a 45-day period in the first year and AI for 42 to 45 days followed by natural mounting in the next ones, also studied the effects of dystocia on subsequent reproduction of beef cattle. According to the authors, the percentage of cows detected in oestrus during the 45-day AI period for all cow ages was 14.4% lower ($P < 0.005$) in those requiring assistance at calving in comparison with calving with no dystocia. Moreover, the conception rate during the same period and the total conception rate were also lower: 15.6% ($P < 0.01$) and 15.9% ($P < 0.005$), respectively, for cows with dystocia in comparison with cases of females without dystocia.

The interval from calving to first breeding and the interval from calving to conception were also studied by Laster et al. (1973). The authors explained that the lower rates of oestrus detection during the artificial insemination period and the lower conception rates in cows having dystocia indicate that these traits are longer in cows experiencing dystocia. However, the authors concluded that this difference was slightly, but not significantly, longer in cows with calving difficult.

Ducrot et al. (1994) found a decrease in the pregnancy rate with the level of calving assistance. The authors observed that the pregnancy rate was 93% when there was no assistance or easy assistance, 92% when there was assistance with a calf puller, 91% in cases of forcible extraction, decreasing to 66% and 79% in cases of caesarean section with or without forcible extraction attempt. Méssinier et al. (1992) also presented the reproductive repercussions of the calving difficulty in beef cattle reproduction. According to the authors, in the Charolais breed, the pregnancy rate was 91.1% when there was no assistance, decreasing to 89.8%, 78.6% and 73.2% when there was easy assistance, forced extraction or caesarean section.

Hanzen et al. (1994) studied the reproductive performance in the Belgian Blue breed, where of the 1 159 calvings recorded in beef herds, 90% required caesarean section. The authors referred suckler beef herds, directed to the meat production, and milked beef herds, a branch of dual-purpose cattle, concluding that primiparous beef cows had higher fertility than pluriparous cows. According to Hanzen et al. (1994), the mean calving interval was 435 days for suckler beef cattle and 401 days for milked beef cattle, existing a general diminution of the calving interval with the number of calvings. However, these differences were not significant.

The mean interval from calving to first oestrus was 88 days in suckler beef cattle and 70 days in milked beef cattle. In both situations, the interval from calving to first oestrus was significantly different between the calving's number. In the case of suckler beef cows ($P < 0.05$), the interval after the first caesarean section was 97 days, decreasing to 83 days, 80 days and 78 days in the successive calvings. In milked beef cows ($P < 0.001$) after the first calving, the interval to first oestrus was 89 days, being 62 days, 54 days and 60 days after the second, third and more than three calvings. Hanzen et al. (1994) also studied the interval from calving to first service, concluding that, on average, it was 90 days for suckler beef herds and 83 days for milked beef herds, diminishing within successive calvings. However, this difference was not significant, the authors explained that in Belgian practice, many farmers still wait 2 or 3 months before commencing service following a caesarean section. Furthermore, the poor oestrus detection reported also delay the first service. So, Hanzen et al. (1994) considered that the interval to first service is the primary factor affecting the calving interval.

In what concerns to average days open after caesarean section, Hanzen et al. (1994) mentioned that this interval was 137 days in suckler beef cows and 122 days in milked beef cows, with a decrease between the first three parturitions and increase after that. This difference was not statistically different in suckler beef cattle; however, in milked beef cows it was ($P < 0.001$).

About the number of services per pregnancy, Hanzen et al. (1994) observed a value of 1.7 services per pregnancy in heifers in both types of production and 2.0 and 2.1 services per pregnancy, respectively, in suckler and milked beef herds. However, in milked beef cattle, this value increased with the number of calvings, being statistically different ($P < 0.01$): 1.7 in heifers, 2.0 after the first and second calvings, 2.3 after the third one and 2.7 in females with more than three caesarean sections. The differences in services that have been observed mainly in cows reflect the long-term adverse effects of caesarean sections in fertility.

As explained above, after parturition, it is necessary to restore the reproductive function so another pregnancy can occur. However, as mentioned by Short et al. (1990) and Peter, Vos, and Ambrose (2009), factors as dystocia can increase postpartum infertility and delay rebreeding, due to a lack of luteal regression that causes a prolonged luteal phase. Opsomer et al. (2000) observed that cows with an abnormal calving are 3.6 times more prone to a risk of resuming ovarian activity significantly later ($P < 0.01$) and 2.9 more times at risk for a prolonged luteal phases during the postpartum period ($P < 0.05$).

In order to explain this delay in the postpartum resumption, some authors defend that a stressful event, such as a difficult calving, can act as an acute stressor, leading to the release of endogenous opioids. These agents will affect the hypothalamic function, resulting in abnormal ovarian function and delay or abolition of the LH surge. In fact, stressors can disrupt the correct functioning of each part of the hypothalamus-pituitary-ovarian axis (Aurich, Dobrinski, Hoppen & Grunert, 1990; Dobson, Tebble, Smith & Ward, 2001).

Although Ducrot et al. (1994) demonstrated that problems during calving were more important than retained placenta as a possible risk factor for postpartum anoestrus; Opsomer et al. (2000) found that cows with puerperal disorders were three times more at risk of delaying the cyclicity. Sheldon et al. (2009) explained that cows with uterine bacterial infections have slower growth of dominant follicles in the ovary and lower peripheral plasma estradiol concentrations and so they are less likely to ovulate. Furthermore, these authors mentioned that the release of GnRH from the hypothalamus and LH from the pituitary could also be suppressed by bacterial lipopolysaccharides (LPS), further reducing the ability of a dominant follicle to ovulate. Even if these cows ovulate, the peripheral concentrations of progesterone are lower than those in normal fertile animals and the luteal phases are often extended, a phenomenon that, probably, occurs as consequence of the switch of the endometrial epithelial secretion of prostaglandins, from the F series (that are luteolytic) to E series (that are luteotrophics).

Considering the culling rate, Rogers et al. (2004) explained that this trait is also affected by dystocia, with cows that experienced dystocia presenting 58% greater risk of being culled ($P < 0.01$). Coutard, et al. (2007) reported that 24% cows were not presented in the next breeding season when there was no or easy assistance, compared to 32% with difficult assistance and 56% in cases of caesarean section or fetotomy. Hanzen et al. (1994) mentioned that after caesarean section, in average, one half of the culled cows were removed because of infertility, reporting 63% in beef milked beef herds and 45% in suckler beef herds. Therefore, Meijering (1984) justified that the higher females culling rate that is observed in dystocia can be due to a number of factors that include the already referred calving lesions, depressed fertility or just concern about repeated calving problems.

Szabó and Dákay (2009) stated that calving difficulty had an effect on longevity ($P < 0.05$). According to the authors, longer productive life was estimated across breeds for cows without assistance (6.23 years) or with a little assistance (6.93 years) compared to those needing veterinary assistance (2.75 years) or having stillbirth (4.63 years). However, is it important to mention that the difference was not significant between no or little assistance and between veterinary assistance and stillbirth, but statistically significant between these two groups ($P < 0.03$).

Table 4 The dystocia as a cause of reproductive performance: summary table

Measures of reproductive performance	**Type of assistance**	**Authors**
Increase calving interval	• From no assistance to caesareans • From no assistance to caesareans • Caesarean section	• Ducrot et al. (1994) • Chambres d'Agriculture des Pays de la Loire (2010) • Hanzen et al. (1994)
Decrease heat detection and conception rate	Difficult vs no difficult calving	• Laster et al. (1973)
Increase interval from calving to first oestrus	Caesarean section	• Hanzen et al. (1994)
Increase interval from calving to first service	Caesarean section	• Hanzen et al. (1994)
Increase number of services per pregnancy	Caesarean section	• Hanzen et al. (1994)
Increase culling rate	• From no assistance to caesareans • From no assistance to caesareans	• Rogers at al. (2004) • Coutard et al. (2007)
Decrease longevity	• From no assistance to caesareans	• Szabó & Dákay (2009)

IV. The influence of the caesarean section in the reproductive performance of Belgian Blue Cattle

1. Introduction

The origin of the Belgian Blue breed remounts to the second half of 19th century, when the first attempts to breed local dual purpose cattle with Sorthorn sires were observed. The objective was clear: a dual purpose breed, with a good stature, average muscle structure and good milk production. However, between 1950 and 1960, preference was granted to the muscular development. Therefore, in 1973, the breed, hitherto called race de Moyenne et Haute Belgique, was renamed Belgian Blue breed and divided into 2 distinct branches: the meat type, which referred animals of extreme conformation, and the dual purpose type, with animals for combined milk and meat production (Belgian Blue Beef Herd-Book).

Relatively early, the muscular hypertrophy in this breed was mentioned and, in 1982, Hanset, Michaux, Dessy-Doize and Burtonboy (1982) recognized that this trait was a result of an increase in the number of muscle fibers (hyperplasia, rather than hypertrophy). So, some years later, Hanset and Michaux (1985) concluded that a major gene was involved in the determination of muscle hypertrophy in Belgian Blue cattle, proposing the symbol *mh* for muscular hypertrophy to identify it. Furthermore, the authors explained that this gene was a partially recessive gene, being the heterozygote (*mh*/+) near the homozygous normal (+/+), while the homozygote *mh*/*mh* had a distinct conformation.

The research about this subject continued and Charlier et al. (1995) mapped the locus referred as muscular hypertrophy in the bovine chromosome 2. Moreover, in 1997, McPherron, Lawler and Lee (1997) described a member of the transforming growth factor β, myostatin, which was expressed in developing and adult skeletal muscle and functioned as a negative regulator of the skeletal muscle mass in mice. Considering this, Grobet et al. (1997) demonstrated that a mutation, characterized by an 11bp deletion in the bovine myostatin gene, cause the elimination of the bioactive part of the molecule, being responsible for the double-muscled phenotype.

As explained by Gama (2002), the double-muscled animals present greater carcass yield and an increase in the muscle and noble parts percentage. However, problems with dystocia are also frequent. In order to remove the problem of difficult calving associated with double-muscling, the caesarean section became generalized in the meat type, being now performed systematically at an early stage of the parturition (Hanset, 1998). Thus, the goals of this study are (1) to understand if there is any difference in the reproductive performance of double-muscled Belgian Blue cows when two different types of sutures were used: Monodox®

(polydioxanone, USP 2, Michel Frere, Belgium) or Monosyn® (polyglyconate, USP 1, Braun, Germany) for the uterus and Surgicryl® (polyglycolic acid, USP 2, SMI, Belgium) or Safil® (polyglycolic acid, USP 2, Braun, Germany) for the peritoneum, muscles and skin and (2) to understand the influence of the caesarean section number in the reproductive performance of double-muscled Belgian Blue cows.

The study realized by Kolkman, Ribbens and Vandaele (2012) in the same animals revealed that the Monodox®, which is composed by polydioxanone, presents more memory in relation to Monosyn®, that is made up of polyglyconate (82 days in comparison to 52 days; $p < 0.001$). However, the females uterine evaluation did not demonstrate differences in size, symmetry, content, uterine involution and presence of adhesions. Therefore, the goal was to understand if the utilization of these different materials in the uterine suture as any influence in the reproductive performance.

The study of the reproductive performance at different numbers of caesarean section surges in consequence to the procedure negative effects that are mentioned in the literature. Thus, the goal was to understand the effect of multiple caesarean sections in the females reproductive performance.

2. Materials and methods

2.1. Data

The data for this study consisted of information on 119 caesarean sections performed in double-muscled Belgian Blue cattle between 03rd October 2008 and 03rd May 2010 at the Instituut voor Landbouw- en Visserijonderzoek - Institute for Agricultural and Fisheries Research (ILVO), in Belgium.

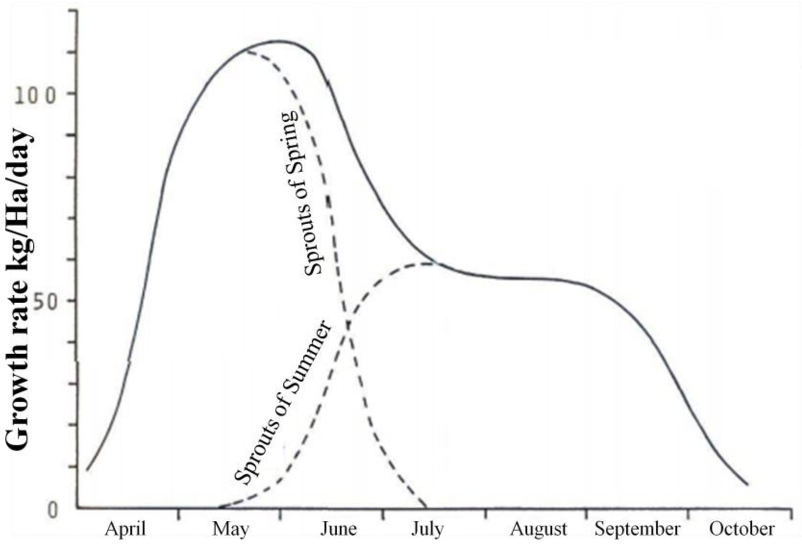
2.1.1. The Institute for Agricultural and Fisheries Research (ILVO), Department Animal

The ILVO is a Flemish research centre located in Melle, Belgium, in the province of the East Flandres, where it is possible to find a nucleus of Belgian Blue double-muscled cattle with a total of 60 to 70 breeding animals.

Figure 6: Location of the Institute for Agricultural and Fisheries Research, Department Animal

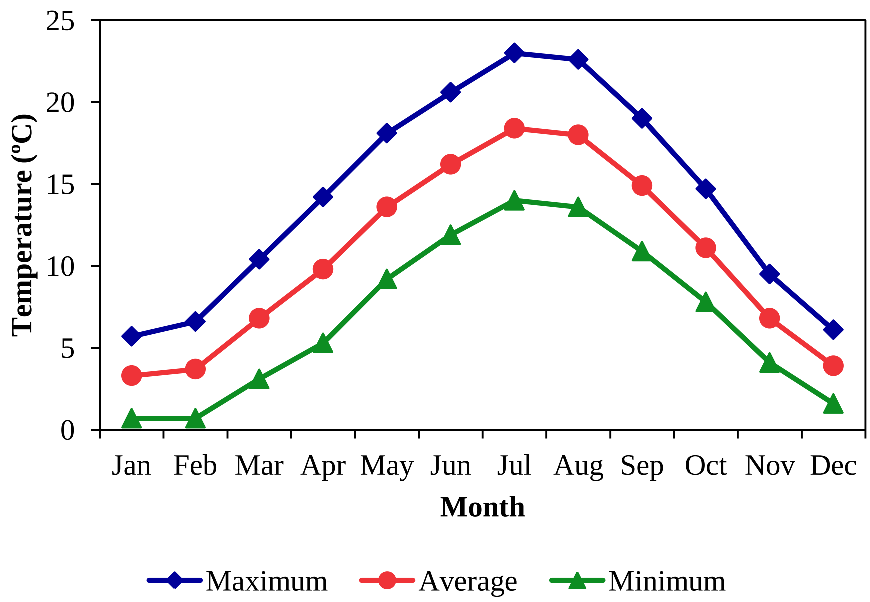
In this farm, the management system includes two distinct periods: the pasture and the stable. From April until November, the animals are at pasture, taking advantage of the grass growth curve (Figure 7). In contrast, from November until April, the cows are at the stables, divided in different groups. During both periods, it is possible to maintain the cows with the bulls, so, mostly, when there is a positive diagnose of pregnancy, the animals are moved and stay housed in group.

Figure 7: Grass growth rate in Belgium (Hubrecht & Willems, 2010)

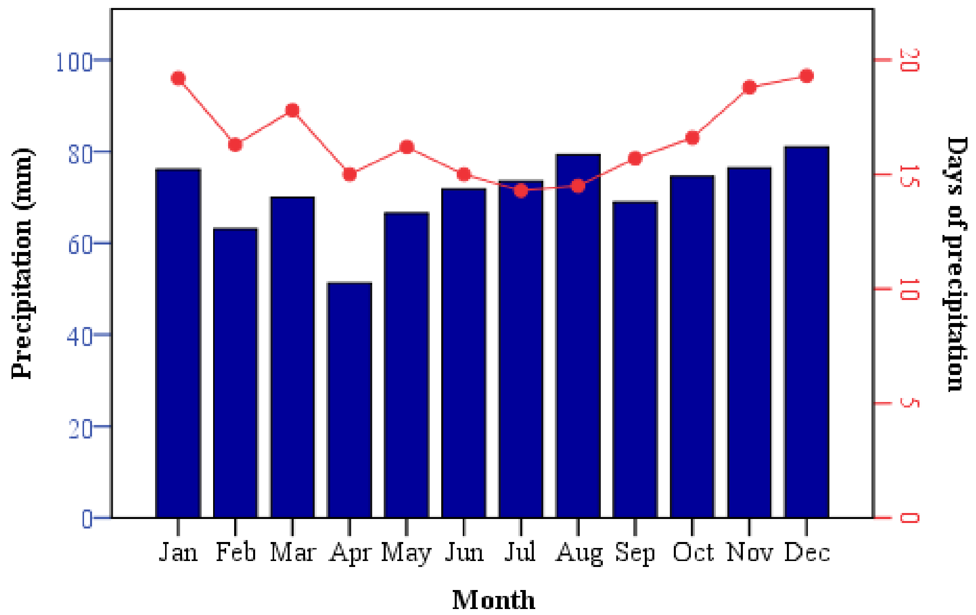


As the climatic conditions interfere with the farm's management, it seems to be important to evaluate this variable. Data from the Royal Meteorological Institute of Belgium (Uccle Station) showed that the average temperature is lower in December (3.9ºC), January (3.3ºC) and February (3.7ºC), being higher in July (18.4ºC) and August (18.0ºC). In April, it is possible to observe an average of 9.8ºC, varying between 5.3ºC and 14.2ºC, in contrast to November when it is registered an average temperature of 6.8ºC, with a minimum of 4.1ºC and a maximum of 9.5ºC (Graphic 3). In what concerns precipitation, according to Graphic 4, it is possible to observe that it is very similar all over the year and occurs every month, varying between 14.3 (July) and 19.3 (December) days of precipitation. The total amount of precipitation is lower in April (51.3 mm) and higher in December (81.0 mm). Regarding snow, the Royal Meteorological Institute of Belgium mentions that it can be observed between the end of November and the beginning of April.

Graphic 3: Evolution of the annual temperature in Belgium (Uccle station, 1981-2010) [adapted from Institut Royal Météorologique (n.d.)]



Graphic 4: Medium annual precipitation in Belgium (Uccle station, 1981-2010) [adapted from Institut Royal Météorologique (n.d.)]



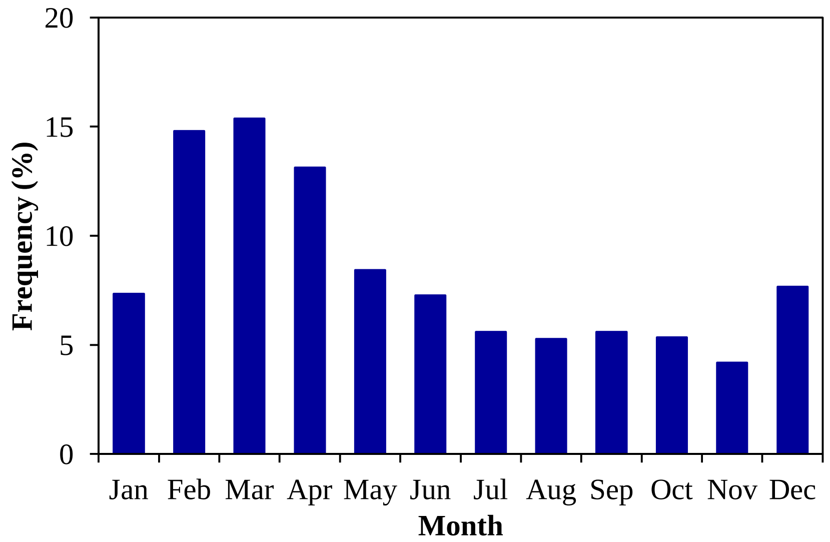
The production system is organized so that the heifers enter the breeding program at, approximately, 375 kg live weight. This goal usually occurs between the 13th and 17th months of age and the heifers are mated by natural service with the youngest bull in the farm, at a ratio between 1:15 to 1:20, maximum 1:30.

In what concerns the cows, after a voluntary waiting period of approximately 1 month, they are mated by natural service with one of the two older bulls. The ratio bull:cows is similar to the heifers and so, if there is no space in one of the groups, the voluntary waiting period can be longer. In some exceptional cases artificial insemination is used.

The bulls in this farm are bought at the Association Wallone de l'Elevage, Ciney, Belgium, with a breeding soundness evaluation and a DNA analysis for genetic anomalies already discovered in the Belgian Blue breed. Furthermore, it is certified that the animals are free for Brucellosis, Tuberculosis, Leucosis, Bovine Viral Diarrhoea and Infectious Bovine Rinotracheitis and vaccinated against the Bovine Syncicial Respiratory Virus.

Considering this breeding policy, it is possible to observe calvings all over the year, although, parturitions are more concentrated between February and April. In fact, as can be seen on Graphic 5, 43.31% of calvings occur during these 3 months.

Graphic 5: Calving distribution in the double-muscled Belgian Blue cattle at ILVO (1989-2013)



As it is necessary to perform caesarean sections, in this study, the animal handlers checked twice daily and registered the rectal temperature so the decrease in this parameter could be noted and the parturition was not missed.

Despite the mechanisms controlling the precalving decline in body temperature remains unclear and there is conflicting information in the literature about the predictive value of the this parameter, several authors reported the decrease in body temperature before parturition.

Noakes et al. (2009) cited Ewbank (1963)[5], who noticed that, on average, 54 hours before calving there was a drop about 0.6ºC on cow's body temperature. Furthermore, the author referred that a healthy cow showing signs of imminent labour would be unlikely to calve within the succeeding 12 hours if its rectal temperature was above 38.8ºC. Lammoglia et al. (1997) also studying this subject mentioned that the decrease in body temperature before calving has been reported as much as 1ºC immediately prepartum, while, according to Streyl et al. (2011), the body temperatures during the last 24 hours before parturition were significantly different to those measured at all other time points ($p < 0.05$) with a mean average decline of 0.3 ± 0.5ºC. In this study, it was expected that calving occurred within 24 hours when the animal handlers registered a drop of 1ºC in the body temperature.

After calving, the calf and the dam are immediately separated and the calf consumes the colostrum from its own mother, with a goal of 4 litters during the first 24 hours. In cases where there is not enough colostrum or if it is not of good quality, the calf is feed with extra colostrum from the Holstein Frisian herd or from the colostrum bank. From day 3 or 4 onwards, the calves are fed with milk replacer, in an amount according to their weight (1 litter of milk replacer for 10 kg of live weight). In exceptional cases, suckling can occur.

In what concerns the destination of the animals born at ILVO, it is important to refer that the females stay in the farm until they can take part of the breeding program, while the males are sold within 2 or 3 weeks of birth.

The culling policy considers, approximately, 20 to 30 cows in feedlot to go to the slaughterhouse every year, being important to mention the older cows (with more than 4 calvings), cows that presented ruminal or uterine adhesions, feet problems or with inadequate conformation. Furthermore, infertility is relevant being that animals that are not pregnant 9 months after the previous calving are normally culled.

2.1.2. Sample characterization

The data for this study was obtained from 119 caesarean sections (CS) performed in 53 heifers (CS 1) and 66 cows. In 30 animals a 2nd caesarean section (CS 2) was realized, in 21 animals a 3rd one (CS 3) and 15 animals were subjected to the four or more caesarean section (CS≥4). The surgery was performed by 16 different veterinary surgeons on the left side of standing double-muscled Belgian Blue cow and the use of the suture group was rotational. Thus, 62 animals (27 heifers and 35 cows) were sutured with Monodox® and Surgicryl®

[5] Ewbank, R. (1963). Predicting the time of parturition in the normal cow: a sutdy of the precalving drop in body temperature in relation to the external signs of imminent calving. *Veterinary Record*, 75, 367.

(group 1) and in 57 animals (26 heifers and 31 cows) Monosyn® and Safil® was used (group 2).

Table 5: Distribution of the 119 caesarean sections studied

CS	**Suture**		**Total**
	Group 1	**Group 2**	
1	27	26	53
2	16	14	30
3	13	8	21
≥ 4	6	9	15
Total	62	57	119

In order to characterize the reproductive performance of this population, the data from each cow was collected. Based on the farm records, it was possible to summarize the animals' breeding history, since they were born until present and to calculate the calving interval and the breeding interval. Furthermore, for animals already culled, it was possible to determine the cause.

2.2. Methods

The farm number and the sanitary number, birth live weight and sire and dam were mentioned for each cow on the farm records. Furthermore, in every calving the date and type of delivery was registered and information about the dam (age, live weight, bull access day) and the calf (farm number, sex, live weight and abortion or not) was collected. The sutures type utilized was also recorded.

2.2.1. Measures of reproductive performance

The parameters chosen to evaluate the suture type and calving's number influence in the reproductive performance were the calving interval and the breeding interval. Furthermore, the culling rate was assessed.

The calving interval is an important measure of the reproductive performance to understand the behaviour of each animal in the breeding program. For every delivery, this parameter was calculated based on the difference, in days, between the calving after the study and the calving when the study was performed.

When interpreting the reproductive data, it is necessary to consider that the calving interval does not explain which is the cause of not achieving the "365 days between parturitions" goal. So, and as the cows are mated by natural service and the length of the voluntary waiting period is approximately constant without information about the cow's cyclicity, the breeding interval was studied. This parameter was calculated based on a 282 days gestation period, which is in agreement with the Belgian Blue Beef Herd-Book that refers the gestation period of the breed to be 281.6 days for females and 282.6 days for males, i.e. a mean of 282.1 days; and considered the number of days that the cow spent with the bull until conception.

As stated previously, it was also referred that the culling rate is higher in cases of dystocia. Therefore, it was evaluated the percentage of animals culled after the caesarean section, with or without access to the bull, and the proportion of animals culled due to reproductive problems.

2.2.2. Statistical analysis

The statistical analysis was performed on the IBM SPSS Statistics 21®, dividing the animals in 8 groups: 1st, 2nd, 3rd and 4th or more caesarean sections for each suture (suture 1 or suture 2). This distribution considered the relative low number of animals with four or more caesarean sections (n = 14).

For each parameter a descriptive statistic was performed: mean and standard deviation, median, percentiles (25% and 75%) and maximum and minimum, as needed to characterize the variables. The measures' distribution was graphically depicted.

For each group, the number of caesarean sections and type of suture was considered and a graphic representation realized to demonstrate the variables evolution in the different groups.

With regards to the quantitative variables (calving interval and breeding interval) it was observed that they did not show a normal distribution. So, a non-parametric test, the Kruskal-Wallis test, was used to evaluate if the number of caesarean sections and/or the type of suture used had a statistically significant influence on the studied measures. As the number of caesarean sections was higher than 30 it was possible to refer the central limit theorem and, subsequently, to perform a two-way ANOVA. The advantage of this test is the possibility to understand if there is any interaction between both factors.

When realizing statistic research, there are more variables that can affect the experiment: called covariates. Therefore, in the calving interval study, an ANCOVA model was used including the breeding interval and the voluntary waiting period. Furthermore, the voluntary waiting period was considered as covariate when exploring the breeding interval variable.

In respect to culling rate (qualitative variable), a non parametric test, the Kruskal-Wallis test, was used to study the possible interaction between each factor (number of caesarean section and suture type) and this variable.

In every statistical analysis the results were considered significant when p-value was inferior to 0.05.

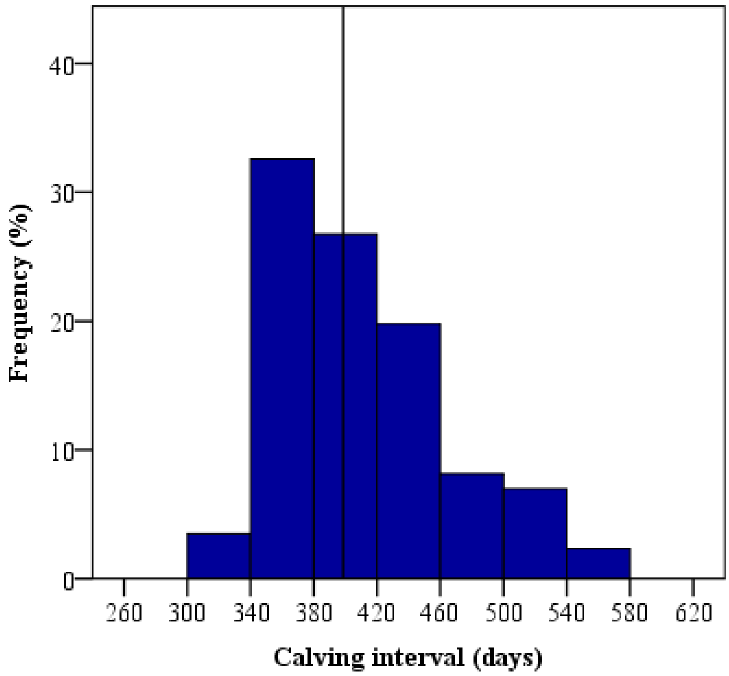
2.3. Results

2.3.1. Calving interval

The descriptive statistics of the variables demonstrated that in the 119 caesarean sections performed, 86 were valid for the evaluation of the calving interval. The 33 values missing correspond to animals that were culled, so there was no information about the reproductive performance after the surgery.

In what concerns the calving interval (Graphic 6) a mean of 411 ± 54 days, with a median of 398.5 days was observed. The distribution demonstrated that 32.6% animals had a calving interval between 340 and 380 days and that only 23.3% calved with a difference lower than 365 days. Furthermore, the minimum calving interval was 319 days and the maximum 557 days, being that 75% of the values were lower than 436 days (percentile 75).

Graphic 6: The calving interval distribution (n=86, DM-BB, ILVO)

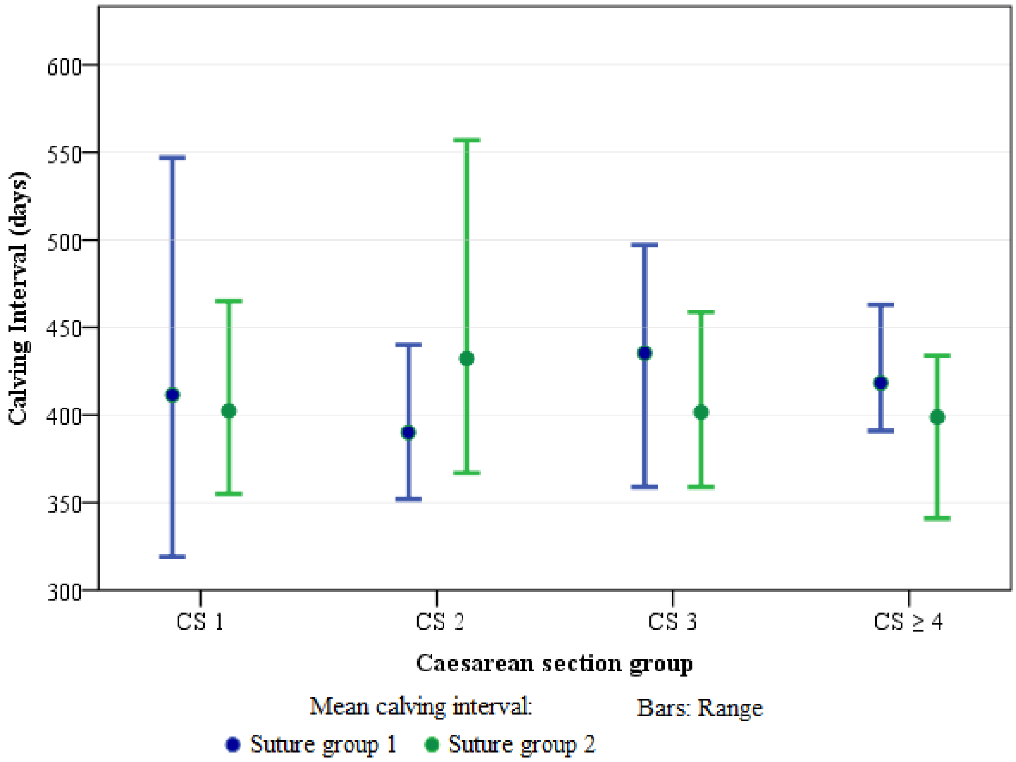


Note: The vertical line represents the median (399 days).

The evaluation of the calving interval per number of caesarean sections and suture group can be observed on Graphic 7. As it is demonstrated, on suture group 1, the mean of this parameter did not follow a regular variation, increasing and decreasing between groups. The higher interval was 418 days, which was observed in cows with more than four caesarean sections, and the lower 390 days, observed between the second and third calvings.

On suture group 2, the calving interval increased from heifers (CS1 - CS2) to second calving cows (CS2 - CS3), decreasing after that. Therefore, the higher mean calving interval was 432 days and was reported between the second and third calvings. The three other groups presented a very similar calving interval: 402 days after the first and third calving and 399 days in animals with four or more caesarean sections.

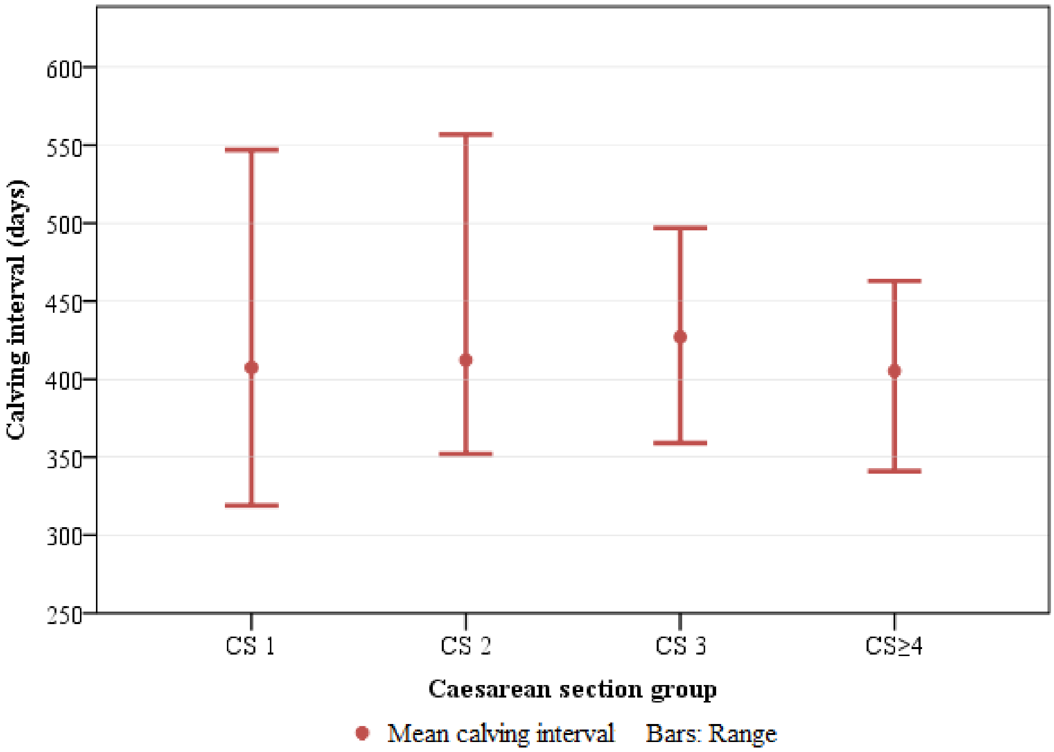
Graphic 7: The mean calving interval by number of caesarean sections and suture group (n=86, DM-BB, ILVO)



Note: The CS1 group corresponds to animals submitted to the first caesarean section and so the calving interval corresponds to the interval, in days, from the first to the second caesarean section. The same procedure was followed in the others groups. In cows submitted to more than 4 caesarean sections (CS ≥4), the mean calving interval was considered between two consecutive surgeries.

The mean calving interval (Graphic 8), increased from the first calving interval (407 days) to the third one (427 days). However, after the fourth parturition, a decrease to 405 days between successive calvings was reported, being the lower value.

Graphic 8: The mean calving interval per caesarean section group (n=86, DM-BB, ILVO)



Note: The CS1 group corresponds to animals submitted to the first caesarean section and so the calving interval corresponds to the interval, in days, from the first to the second caesarean section. The same procedure was followed in the others groups. In cows submitted to more than 4 caesarean sections (CS ≥4), the mean calving interval was considered between two consecutive surgeries.

The influence of the caesarean section group in the calving interval analysis with Kruskal-Wallis test (Table 7) showed that the differences observed in the calving interval according to the number of caesarean sections were not statistically significant ($p = 0.647$). In respect to the suture group (Table 7), it was also reported that the calving interval did not vary significantly among the clusters ($p = 0.928$).

Table 6: The effect of the caesarean section number and suture group on the calving interval: the Kruskal-Wallis test results (n=86, DM-BB, ILVO)

Parameters	Caesarean section number	Suture group
Chi-square	1.654	0.008
df	3	1
Asymp. Sig.	0.647	0.928

The fact that there was no effect of both factors in the calving interval was also demonstrated with the two-way ANOVA test. As it can be observed on Table 8, although there were variations in the calving interval, the number of caesarean sections did not have a statistically significant effect (p = 0.947) on this variable. The same occurred when analysing the influence of the suture group factor (p = 0.739). In what concerns to both factors, caesarean section and suture group, no statistically significant interaction (p = 0.217) could be observed. On this analysis, the determination coefficient (R^2) was 0.070, which means that only 7.0% of the calving interval variation was explained by the studied factors.

Table 7: The effect of the caesarean section number and suture group on the calving interval: the two-way ANOVA test results (n=86, DM-BB, ILVO)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	17598.563[a]	7	2514.080	0.839	0.559
Intercept	8824802.730	1	8824802.730	2944.295	< 0.0001
Caesarean section group (CS)	1093.176	3	364.392	0.122	0.947
Suture group (G)	335.763	1	335.763	0.112	0.739
CS * G	13622.844	3	4540.948	1.515	0.217
Error	233785.868	78	2997.255		
Total	14784345.000	86			
Corrected Total	251384.430	85			

[a.] R Squared = 0.070 (Adjusted R Squared = - 0.013)

As shown on Table 9, the use of the voluntary waiting period and breeding interval covariates did not change the non significant effect of both factors in the calving interval: p = 0.935 for the caesarean section group and p = 0.926 for the suture group. However, the determination coefficient (R^2) increasd to 60.8%, and so augments the rate of variation explained by both factors. In fact, the influence of both covariates in the calving interval demonstrated a statistically significant effect (p < 0.0001).

Table 8: The effect of the caesarean section number and suture group on the calving interval: the ANCOVA test results(n=86, DM-BB, ILVO)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	135360.570[a]	9	15040.063	10.358	< 0.0001
Intercept	1305549.410	1	1305549.410	899.095	< 0.0001
Voluntary Waiting Period	46186.452	1	46186.452	31.807	< 0.0001
Breeding interval	86856.224	1	86856.224	59.815	< 0.0001

Table 9: The effect of the caesarean section number and suture group on the calving interval: the ANCOVA test results(n=86, DM-BB, ILVO) (continuação)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Caesarean section group (CS)	613.102	3	204.367	0.141	0.935
Suture group (G)	12.657	1	12.657	0.009	0.926
CS * G	3349.029	3	1116.343	0.769	0.516
Error	87124.230	60	1452.071		
Total	12313120.000	70			
Corrected Total	222484.800	69			

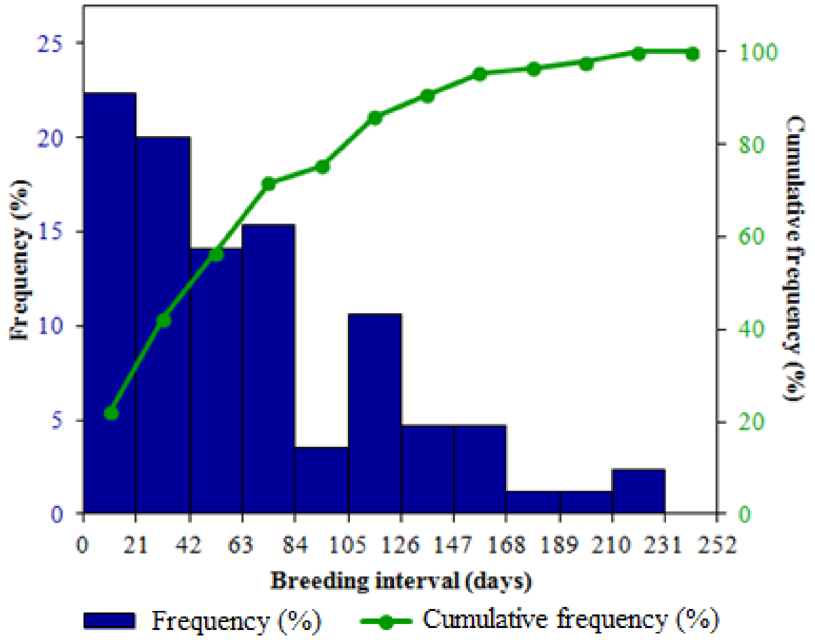
a. R Squared = 0.608 (Adjusted R Squared = 0.550)

2.3.2. Breeding interval

With respect to breeding interval, it was observed that only 85 values were valid. This difference is due to a missing value in the day that the cow was moved to the group with the bull, which did not allow for the calculation of this parameter.

The breeding interval descriptive statistic (Graphic 9) demonstrated an average of 66 ± 54 days, with a median of 53 days between the bull access and conception. It ranged from 0 to 214 days with 95% animals being bred before 147 days. Furthermore, analysing Graphic 9, that represents the cumulative percentage of animals conceiving during the breeding interval, it was possible to infer that 22.4% animals conceived during the first 21 days, 42.4% in a 42-day period and after 63 days 56.5% animals were pregnant.

Graphic 9: Breeding interval distribution (n=85, DM-BB, ILVO)

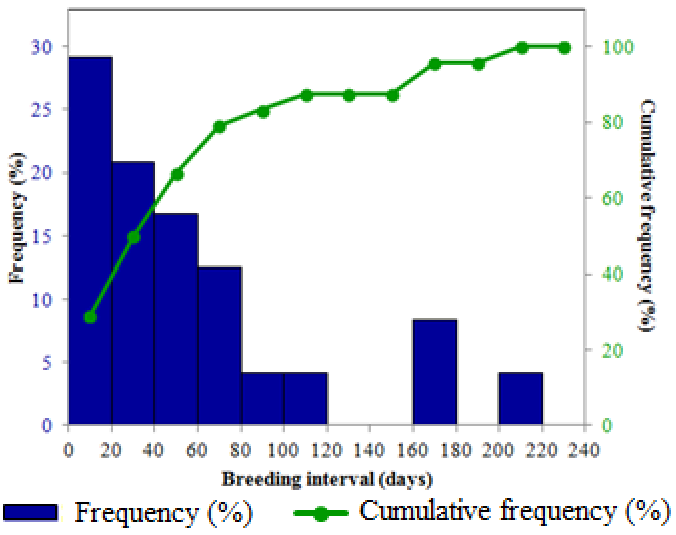


As explained during the literature review, the 3-year old females are the most difficult group to get rebred as it is necessary to consider the growth requirements, while calving and nursing the first calf. Therefore, the breeding interval after the studied caesarean section was divided for primiparous cows (Graphic 10) and multiparous cows (Graphic 11). As the average length of the oestrus cycle is 20 days in heifers and 21 days in cows, the normal ranges being 18 to 22 days and 18 to 24 days, respectively (Noakes et al., 2009), the graphic classes consider this difference.

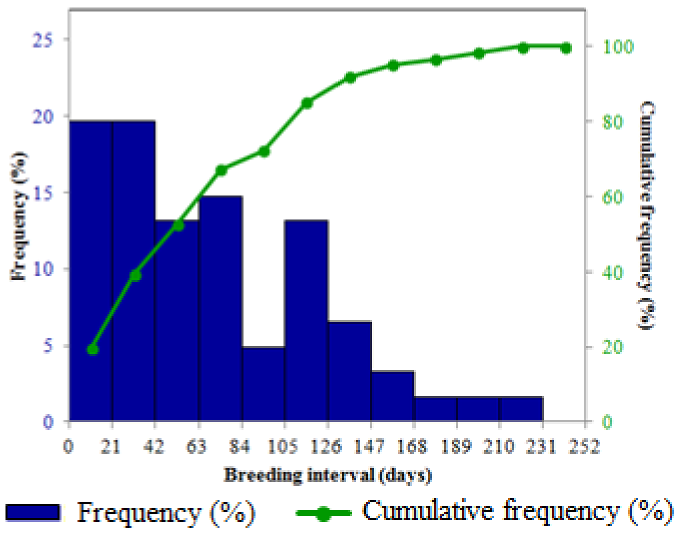
In what concerns the breeding interval after the first calving, it was observed that 29.2% animals were bred within 20 days and 50.0% after 40 days. After 60 days, 66.7% were considered pregnant. Moreover, 87.5% animals were bred 120 days after the bull access, two animals (8.3%) conceived between 160 and 180 days and one animal (4.2%) between 200 and 220 days.

Analysing the breeding interval in multiparous cows, it was found that during the first 21 days 19.7% animals were bred, 39.3% cows were pregnant after 42 days and 52.5% after 63 days. During every 21 days, cows were bred and 168 days after the bull access 95% cows conceived.

Graphic 10: The breeding interval distribution after the first calving (n=44, DM-BB, ILVO)

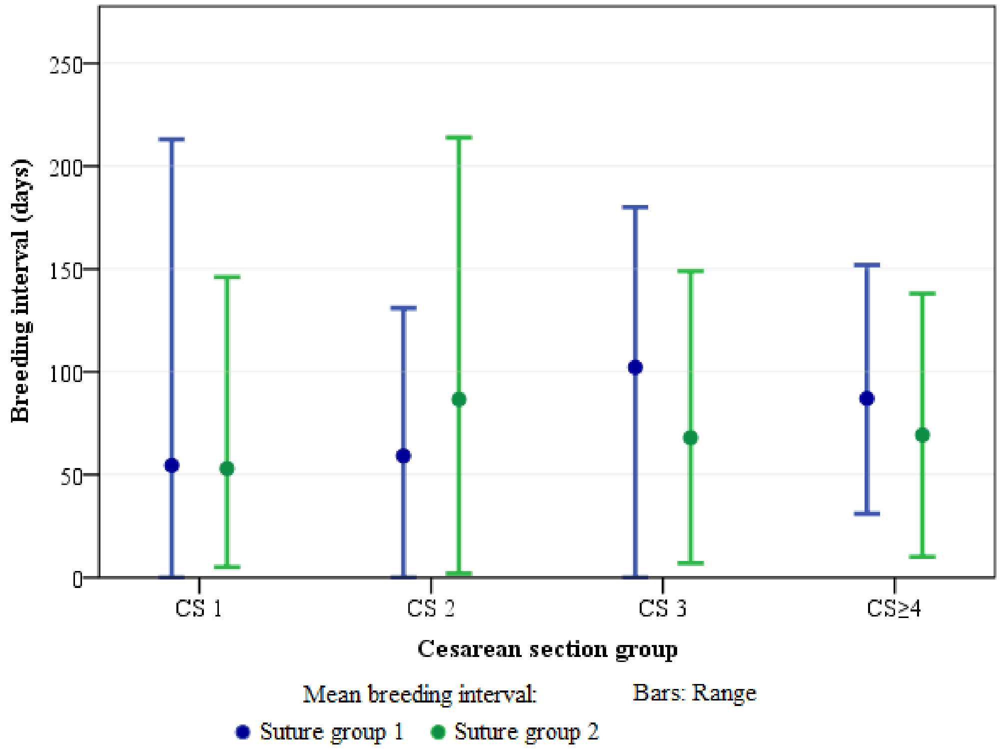


Graphic 11: The cows breeding interval distribution (n=41, DM-BB, ILVO)



The evaluation of the breeding interval per number of caesarean sections and suture group can be observed on Graphic 12. Analysing the suture group 1 a non linear increase of the breeding interval was found between the first and third caesarean section: 55 days after the first caesarean section, 59 days on the second, increasing to 102 after the third elective surgery. Animals that had four or more caesarean sections presented a mean breeding interval of 87 days. The suture group 2 presented the lower breeding interval after the first caesarean section, with a mean of 53 days between the bull access and conception. This parameter increased after the second caesarean section (87 days), decreasing in the third calving (68 days). Cows that had four or more caesarean sections presented a mean breeding interval of 69 days.

Graphic 12: The mean breeding interval by number of caesarean sections and group of suture (n=85, DM-BB, ILVO)



Note: The CS1 corresponds to animals submitted to the first caesarean section and so the breeding interval is the time period with the bull until the females become pregnant again. The same procedure was followed in the others groups. In cows submitted to more than 4 caesarean sections (CS ≥4), the mean breeding interval was considered between two consecutive pregnancies.

Analysing the influence of the caesarean section number in the breeding interval (Table 10), it was found that the differences observed in the breeding interval according to this parameter were not statistically significant ($p = 0.094$). With regard to the suture group (Table 10), it was also demonstrated that the breeding interval did not vary significantly among the populations ($p = 0.940$).

Table 10: The effect of the caesarean section number and suture group on the breeding interval: Kruskal-Wallis test results (n=85, DM-BB, ILVO)

Parameters	**Caesarean section number**	**Suture group**
Chi-square	6.387	0.006
df	3	1
Asymp. Sig.	0.094	0.940

The fact that there is no effect of both factors in the breeding interval was also demonstrated with the two-way ANOVA test. As it can be observed on Table 11, the differences between the populations when clustered by the caesarean section group were not statistically significant ($p = 0.265$). Considering the influence of the suture group factor, the same effect was observed ($p = 0.667$). In what concerns the study of both factors it was noted that there was not a statistically significant interaction ($p = 0.493$).

With respect to the analysis determination coefficient (R^2) it was observed a 0.100 value, which means that only 10.0% of the variation in the breeding interval was explained by the studied factors.

The influence of the voluntary waiting period as a covariate was also included. Since animals that had a small period from calving to breeding, could not be physiologically prepared to conceive, this period was also considered. However, it was observed that it had not a statistically significant effect ($p = 0.376$) in the breeding interval.

Table 11: The effect of the caesarean section number and suture group on the breeding interval: ANOVA test results (n=85, DM-BB, ILVO)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	24852.900[a]	7	3550.414	1.224	0.300
Intercept	271515.267	1	271515.267	93.567	< 0.0001
Caesarean section group (CS)	11747.787	3	3915.929	1.349	0.265
Suture group (G)	540.272	1	540.272	0.186	0.667
CS * G	7031.358	3	2343.786	0.808	0.493
Error	223440.323	77	2901.822		
Total	624384.000	85			
Corrected Total	248293.224	84			

[a.] R Squared = 0.100 (Adjusted R Squared = 0.018)

2.3.3. Culling rate

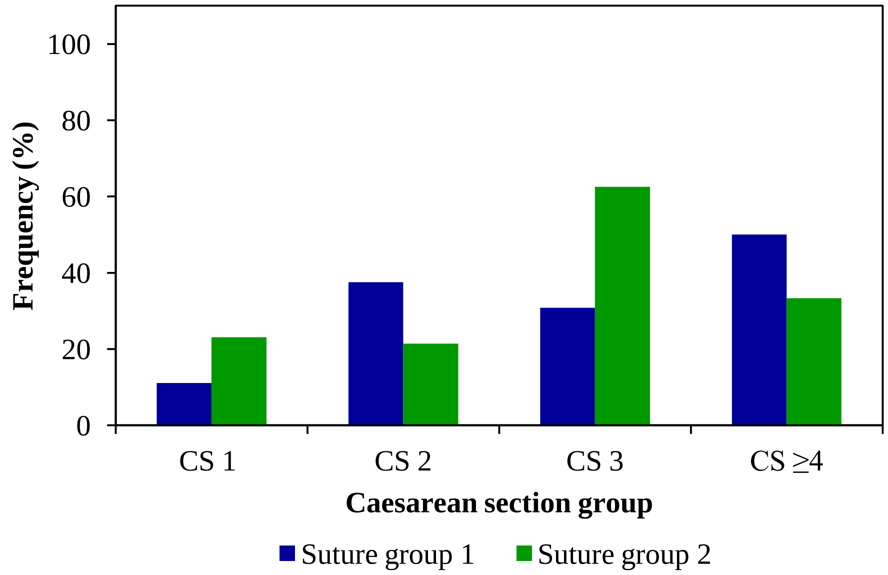
With respect to the culling rate analysis, all the animals were evaluated, and so, the sample considered 119 values. As explained before, in total, there were 33 animals culled, which corresponded to 28%, in contrast with 72% animals not culled. Furthermore, it was observed that after the use of the suture group 1, 26% animals were culled in contrast to 30% in the group in which suture 2 was used.

The culling rate per number of caesarean sections and suture group is analysed in Graphic 14 that represents the percentage of animals culled in each group. In what concerns the suture group 1, it was possible to observe that there is no linear evolution of the culling rate. However, the percentage of animals culled after the first caesarean section (11%) presented the lower value. In contrast, the group of animals with four or more caesarean sections (CS ≥ 4) showed a 50% culling rate after the surgery.

Analysing the culling rate after the use of the suture group 2, a variation between 21% (after the second caesarean section) and 63% (after the third caesarean section) was observed. Furthermore, it was possible to indicate that this parameter follows a non-linear variation.

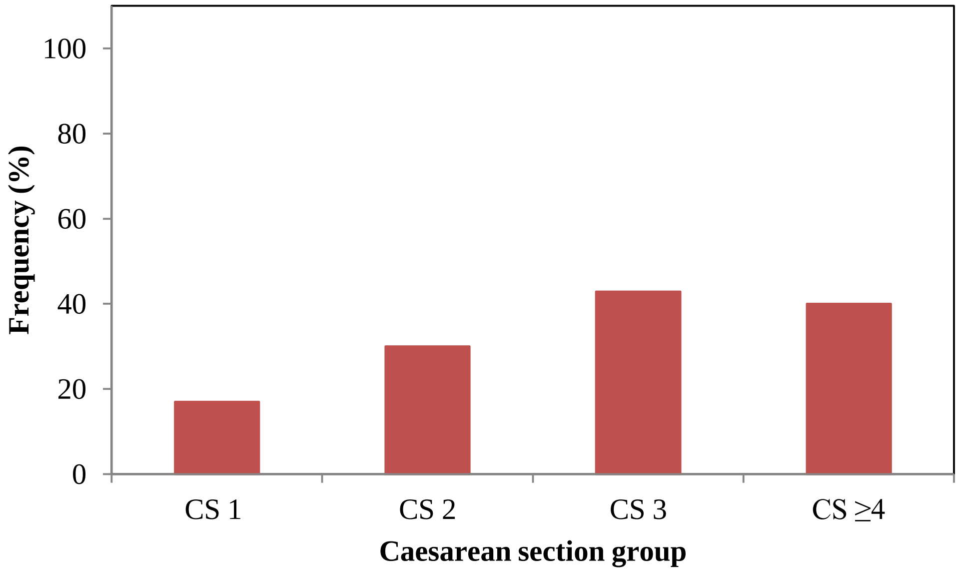
The general culling rate by caesarean section (Graphic 15) demonstrated that after the first three caesareans there is an increase in this parameter when the number of surgeries already performed augments: 17% of the animals subject to the first caesarean section were culled after the surgery in comparison with 30% after the second caesarean section and 43% after the third. In animals with four or more caesarean sections the culling rate was 40%.

Graphic 13: Culling rate analysis per number of caesarean sections and suture group (n=33, DM-BB, ILVO)



Note: The caesarean section group 1 corresponds to animals culled after the first caesarean section. The same procedure was followed in the others groups.

Graphic 11: Culling rate analysis per number of caesarean section (n=33, DM-BB, ILVO)



Note: The caesarean section group 1 corresponds to the animals culled after the first caesarean section. The same procedure was followed in the others groups.

Analysing the influence of the number of caesarean section in the culling rate with the Kruskal-Wallis test (Table 12), it was found that the differences between groups were not statistically significant ($p = 0.086$). In respect to the suture group, it was also noted that the culling rate did not vary significantly among the samples ($p = 0.626$).

Table 12: Analysis of the culling rate: Kruskal-Wallis test results (n=33, DM-BB, ILVO)

Parameters	Caesarean section number	Suture group
Chi-square	6.601	0.237
df	3	1
Asymp. Sig.	0.086	0.626

In what concerns the slaughter causes, it was observed that, after the studied caesarean section, 70% of the removed animals were culled due to reproductive problems, being the main reason not conceiving (78%). Therefore, most females were culled because, as explained before, they do not conceived 9 months after the previous calving.

The cull by reproductive causes considering the number of caesarean section and suture group was also observed. However, although all groups presented cases in this condition, the number of animals was too low to provide a realistic evaluation.

3. Discussion

3.1. Calving interval

In this study, the mean calving interval was 411 days, which is in agreement with the literature. In the Belgian Blue breed, Hanzen et al. (1994) referred a 401 days mean calving interval in milked beef cattle, while the breed Herd Book mentioned 14 months.

Although, this interval is higher than the 365 days proposed as an optimal period or the 380 days proposed by Morrow (1980) as a more realistic goal, it may reflect the decrease of the reproductive performance in consequence to caesarean section. This evidence was also reported by the Chambres d'Agriculture des Pays de la Loire (2010) and Ducrot et al. (1994), who found an increase in the mean calving interval when a caesarean section was performed in comparison to calvings with no assistance. According to the first authors there was an increase in the mean calving interval from 388 to 414 days in the Limousine breed, from 391 to 425 days in the Blonde d'Aquitaine, from 394 to 442 days in the Charolais and from 402 to 442 days in the Rouge des Prés. Furthermore, Ducrot et al. (1994) reported an increase in the mean calving interval from 369 to 399 days after a caesarean section without forcible extraction attempt, which correspond to the practiced at ILVO and more generally in Belgium. Analysing the calving interval distribution it was observed that 75% of the values were lower than 435.5 days, which is equivalent or below the mean calving interval found by some of the mentioned authors. In one hand, it is possible to infer that, although only 23.3% animals calved below the optimal goal, the results are in accordance to the expectances considering the utilization of the caesarean section. However, it is necessary to considerer the 25% of animals that had higher calving intervals. From a productive point of view, referring the sum of the average delay, these animals represent a loss of about 3 calves just by the increase of the calving interval in relation to the 436 days, which obviously has an economic significance to the farm. Furthermore, it is important to comment that, according to the farm culling policy, cows that become pregnant before the 9 months after the previous calving are, usually, not culled. However, as it is possible to observe, when conceiving 5 months after the previous calving (and so, having a calving interval higher than 436 days) the females represent an economic loss to the farm.

The interval between two consecutive parturitions, calving interval, can be divided into three distinct periods: the interval from calving to breeding, the interval from breeding to conception and the gestation period. Consequently, an increase in any of these components can reflect in an augment in the calving interval. In this specific case, it was demonstrated that the first two measures had a significant effect in the calving interval ($p < 0.0001$) when studied as covariates.

In what concerns the interval from calving to breeding, it was observed that, in average, the cows were placed with the bull 50 days after calving, being verified a range from 0 to 105 days, without significant differences ($p > 0.05$) between the groups. The outliers represented values above 136 days and so, in this specific evaluation, were not considered, since this was a consequence of the farm's management policy.

Analysing this period, it is possible to understand that the mean 50 days is lower than the 60 days of postpartum rest proposed by Morrow (1980). Furthermore, Rice (1986) reinforced that even when cows show oestrus at less than 50 days postpartum, the conception rates are below 50%. Thus, generally, it is possible that these cows were placed with the bull to early, which would increase the breeding interval, but not the calving interval. In fact, as the cows can be not prepared to conceive when mated by the bull it is reasonable to accept an increase in the breeding interval. However, the calving interval should not be altered since the higher breeding interval must be compensated by the lower period from parturition to breeding.

Nevertheless, as mentioned before, the study of the voluntary waiting period as covariate had a significant effect in the calving interval ($p < 0.0001$). As in this analysis the values above 136 days (outliers) were considered, it should be referred that, in most part, this statistically significance occurs as a consequence of the outliers and so the management policy of the farm.

Although the breeding interval will be discussed in the next chapter, it is interesting to understand that, as mentioned before, if the cows were not cycling when placed with the bull an increase in this period did not necessarily reflect an increase in the calving interval. However, there were cases where even cycling cows together with the bull did not conceive. In this last case, an increase in the calving interval could be explained.

Regarding the gestation period, it is important to mention that, in this study, it was considered a 282 days, which is according to the breed reference. Although it could be possible to observe some variation, Hanzen (2009) explained that the most frequent cause of apparently prolonged gestation is the human error, including inaccurate records that should be referred. Furthermore, though the same authors mentioned the other causes as rare, it must be said that the purchased bulls had a DNA analysis that certificate they were non carriers of the prolonged gestation gene, an abnormality characterized by a foetal adenohypophyseal hypoplasia and a gestation length that can last up to 14 months (Cornillie, Van den Broeck & Simoens, 2007). Therefore, although the human error cannot be disregard, it seems to be plausible to mention that this interval does not play a major influence in the increase of the calving interval.

In what concerns the influence of the suture material in the calving interval, it was observed that there was no significant difference between the populations. In fact, this would be the expected result since, as mentioned before, in an earlier study about these same cases, Kolkman, Ribbens and Vandaele (2012) referred that the uterine evaluation of the females by rectal examination did not demonstrate significant differences in the size, symmetry, content, uterine involution and presence of adhesions, although the suture 1 (Monodox®) has been detected longer than the suture 2 (Monosyn®) (82 days in comparison to 52 days; $p < 0.001$). Furthermore, it is important to note the high variability in each group, which, instantly, does not reflect a significant difference between the groups.

Considering the number of caesarean sections performed, an increase in the calving interval with cow's age was expected as a consequence of the long-term adverse effects of the surgery. However, the mean calving interval was similar, not presenting a significant difference between groups, a result in agreement with the findings of Hanzen et al. (1994).

There are two main explanations to an approximately constant mean calving interval. According to Carolino et al. (2000), the age of the dam has a quadratic effect in the calving interval, being greater in heifers and in cows of more than 8 years old. Since the older cow was 7.5 years when it calved, a balance can be expected between the consequences of the caesarean section that tends to increase this interval and the age that tends to the opposite site. Furthermore, the high variability of the values did not allow to find differences with the Kruskal-Wallis test.

Although these two factors can affect the calving interval, their influence was not statistically significant in the calving interval. Referring the determination coefficient of the ANOVA, the studied factors just explained 7% of the calving interval variation, which is too low and, in fact, is according to the results explained above.

As previously mentioned, the evaluation of the calving interval using as covariates the calving to breeding interval and the breeding interval, demonstrated that these factors significantly influenced the calving interval ($p < 0.0001$), which increased the determination coefficient to 60.8%. Therefore, it is important to refer that the farmers must considerer these periods when evaluating the calving interval.

3.2. Breeding interval

In the present study, the mean breeding interval was 67 days, which, considering a 21 days oestrus cycle, means that, in average, the cows could have been mated 3.2 times before they get pregnant. Moreover, it was observed that the cows' pregnancy goal of 95% was just achieved after 167 days, when it should occur by day 63 in a breeding season (Rice, 1986).

Regarding the results after the first calving it would be expected that, in the same period, 85% or more females should be pregnant, which was just verified after 120 days. One explanation for these results can be achieved by evaluating the time between calving and breeding. As mentioned before, the mean interval between a cow calving and being placed with the bull was 50 days. However, this period can be too small if considered that cows submitted to a caesarean section can present a delay in the resumption of the ovarian activity in consequence to the opioids release during parturition; moreover, uterine infections can occur as a complication of this procedure, also influencing the resumption of the ovarian activity; in fact, Morrow (1980) proposed a 60 days postpartum rest in order to achieve better conception rates, in comparison with the 50% or below at 50 days after parturition (Rice, 1986).

Another issue that needs to be mentioned is that the cows were not systematically evaluated before being placed with the bull. In this trial, the calved cows were checked 10 days after parturition and, after that, all the females were evaluated monthly. However, a reproductive evaluation of these females before entering in the breeding season would help to understand the individual reproductive status, allowing for the utilization of some protocols when recommended in order to correct situations like anoestrus. At the same time, the evaluation of the body condition score could be also important, since too thin animals negatively influence the reproductive performance. As it is understandable, these factors can affect the conception and, therefore, it is appropriate to consider that the distribution of the breeding interval can be partially justified by animals that are not in the best conditions to be bred. Although the study of the time between calving and breeding influence in the breeding interval did not demonstrate a significant result ($p > 0.05$), it seems to be important not to disregard this point.

Management is also important because, as explained before, the production system of this herd is organized so that cows are placed with the bull at a ratio between 1:15 to 1:20, maximum 1:30. When there are too many females to be bred two options are available: increase the postpartum rest period or withdraw cows that are already with the bull for a longer time. However, when performing this last option, it is possible that some cows should not be pregnant and so they will need to be bred again. As the bull access was based on the first record when the female was placed with the bull and the conception date was calculated retrospectively considering the 282 gestation days, some animals that seem to had a longer breeding period, actually where placed with the bull during more than one time, which means that they were not continuously bred. Therefore, the increased breeding interval in this situation it also unreal, not corresponding to a reproductive problem.

The breeding distribution presented can also be a consequence of a process affecting conception or early gestation. In this explanation both early and late embryonic mortality can be included, since the heat detection is not practiced and so an increase in the interestrual interval would not be noted. Furthermore, the abortion should also be considered, although just in a very early stage and during the period when the animals are in pasture, since it can be very difficult to detect the foetus in these conditions. To reinforce this justification, it was interesting to observe that three first calving animals were bred after 120 days, which means that they were really distant of the breeding goal purposed; moreover, representing a complete different behaviour in relation to the rest of the group and reflecting sporadic cases, these animals can be in accordance to the accepted embryo loss accounts referred in the literature review.

With respect to the factors that can influence the conception and early gestation, in addition to all the components above mentioned that include reproductive disorders, the interval from calving to breeding and the body condition score, it could also be important to refer the influence of genetic factors and other environmental factors like the climate, nutrition, infectious agents, plants and toxins and stress. The influence of the bull will be discussed further down.

As mentioned in the literature review, the body condition score plays an important role in beef cattle reproductive performance. However, it is necessary to considerer not only the cattle energy requirements and body condition score variation and the protein levels, but also the minerals and micronutrients. Noakes et al. (2009) cited McClure (1994)[6] and Lean, Westwood, Rabjee and Curtis (1998)[7] in order to explain this interaction. These cited authors suggest that micronutrients can affect the reproduction through four different pathways: the depression of the ruminal microflora activity; the reduction in enzyme activity which consequently exerts an effect on energy and protein metabolism and the synthesis of hormones; the influence in the activity of rapidly dividing cells within the reproductive system; and the antioxidant properties that protect the cells. Therefore, it seems to be interesting to perform not only a systematically evaluation of the body condition score, but also assess the feeding composition, including the minerals and micronutrients.

Still with regard to the nutritional topic, it is necessary to note that there are some plants that affect the reproductive function. According to Youngquist and Threlfall (2007), the true incidence of toxin-induced reproductive dysfunction is unknown. Therefore, although the authors referred that it is presumably well below to the infectious and management problems,

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[6] McClure, T. (1994). *Nutritional and metabolic infertility in the cow*. Wallingford: CAB INTERNATIONAL

[7] Lean, I., Westwood, C., Rabjee, A., Curtis, M. (1998). Recent advances in nutrition and reproduction in temperate dairy management. In W. Webber (Ed.), *Proceeding of the Society of Dairy Cattle Veterinarians of the New Zealand Veterinary Association Annual Conference*, pp. 87-118. Palmerston North: VetLearn Foundation.

it should be pointed as a possibility, since an extensive examination of the pasture was note done.

The influence of the climate in conception rate is also well known. As explained by Noakes et al. (2009) the environmental temperature can influence the expression of oestrus and the pregnancy establishment. Nevertheless, it should only be considered in the presence of high temperatures and more frequently in dairy than beef cattle.

Although the climate is not apparently adequate to justify the results obtained it is important to refer its influence, since the climate during the study period was not evaluated.

There are infectious agents that can also explain the breeding interval distribution observed. Its effect on the reproductive performance can occur by a direct or indirect pathway, however, Noakes et al. (2009) explained that it can culminate in a reduction of the fertilization rate by impaired sperm survival or transport in the female tract or in the embryonic or foetal death, as a consequence of effects on the concept and/or on the uterine function.

Although several infectious agents can affect the breeding interval and so this factor cannot be disregarded, it is relevant to refer that this farm practices sanitary policies that reduce the entering of those agents, including the supply of overalls and boots, and the bulls are considered of Brucellosis, Tuberculosis, Leucosis, Infectious Bovine Rinotracheitis and Bovine Viral Diarrhoea.

According to Youngquist and Threlfall (2007) there are evidences that the social factors can also affect the reproductive function. In the present studied situation it is important to consider this effect since the cow groups are changed with some frequency as a consequence of the farm's breeding policy.

Finally, it is important to remark that the bulls can contribute to the embryonic mortality, but also be partially responsible to the breeding interval distribution as a consequence of its own breeding soundness. The importance of this situation should be investigated more carefully, especially in the cows breeding distribution, since when this group was evaluated, two bulls were being considered at the same time. Nevertheless, as explained before, the breeding soundness evaluation is only performed in the station where the animals are purchased. In a normal situation, the bulls are bred during three years, and so, when analysing this data, it is necessary to regard that injury can occur, being observed repercussions in the females' reproductive performance.

Evaluating the influence of the number of caesarean sections and suture group in the breeding interval, no statically significant differences were observed. As mentioned earlier, there is a high variability of the breeding interval values and so it was not possible to detect differences between populations with the Kruskal-Wallis test.

With regard to the ANOVA results, it should be mentioned that both factors (caesarean section number and suture group) did not have a significant influence in the breeding interval, which support the results of the previous test. However, it is of special concern that the determination coefficient was 10.0%, and so it is proposed the evaluation of other factors in order to understand the reason for so high variability.

3.3. Culling rate

Analysing the culling rate, it was observed that after the caesarean section 28% animals were culled. This value is according to the 25% goal suggested by Morrow (1980), but superior to the 12% found by Hanzen et al. (1994) in milked beef cattle.

Referring the culling rate by number of caesarean sections, it was observed that the higher values correspond to the animals culled after the third and fourth or more elective surgery, which is also in accordance to the expected results considering the culling policy of the herd. Actually, with the increase in the number of caesarean sections, there is usual an increase in the culling rate not only because of the age, but also by the adverse long-term effects of the caesarean section. In this study, it is possible that these effects were not so evident as a consequence of the small number of animals per group. Furthermore, cows with more than four caesarean sections were in the same group (CS≥4) as a result of the low animals number with more than four elective surgeries. Although this organization has demonstrated advantages in the evaluation of the other variables, in this specific situation it can disguised the true factor effect.

Regarding the culling rate per number of caesarean sections and suture group, it can be referred that a significant effect of the variables was not demonstrated. Although this was the expected result, since the groups are considered to be homogenous and the reproductive performance was similar in both of them, the validation of this analysis is doubtful, because the major group had only 5 animals. Therefore, it is noted that a more realistic idea could be achieved after the collection of more records.

In what concerns to the analysis of the culling causes, it was observed that the major culling cause was reproductive problems, being that 69.7% of the culled cows were removed because infertility. Moreover, it was reported that the most frequent reproductive cause for culling was not conceiving (78.3%), which means that the majority females were not pregnant 9 months after the previous calving. At herd level, the animals culled by reproductive causes represented 19.3% of all females. Although this value is extensively higher than the 10% goal to involuntary culling proposed by Morrow (1980) and the 63% milked beef cattle removed because of infertility found by Hanzen et al. (1994), the results are according to the expectances. In fact, it reflects not only the caesarean section consequences already mentioned, but also the breeding interval results that demonstrated that the purposed goals were not achieved.

IV. Conclusion

The reproductive performance is one of the keys in livestock production. In dairy herds, this trait is really important in order to achieve the best results in the major outcome: the milk production. In beef herds, the calf is the most relevant output and so it is necessary that not only the females have an optimum reproductive performance to obtain a viable calf every 12 months, but also that an optimum reproductive cycle is maintained during their productive life in order to maximize the cow profitability.

The veterinary surgeon plays an important role in this topic. With the aim of obtaining the best results it is important that the veterinary surgeon stimulate the farmer to have more and better records, so that a correct analysis can be realized. In fact, this would permit the implementation of a herd health program, appropriate to each farm and considering not only the type of production, but also the goals and available conditions. Furthermore, the existence of those practices would permit a planned adjustment according to the situation.

When considering the implementation of a herd health program, it is necessary to understand that it does not include only the reproduction practices, but it is important to evaluate the farm as a whole. Furthermore, a regular evaluation of the productive cycle key points should be considered and realized. In fact, a good plan would permit a better and quicker detection of the farm problems.

Although considering all these opportunities to improve the livestock production, the investigation of the reproductive performance goals should also be mentioned. Despite being possible to understand what the main goals are and the means to achieve them, the evaluation of the goals distribution would also be important, since it can represent important outcome losses to the farmer.

In what concerns the study performed, it was concluded that the number of caesarean sections and the utilization of Monodox® or Monosyn® for the uterus and Surgicryl® or Safil® for the peritoneum, muscles and skin, does not have a significant influence in the calving interval, breeding interval and culling rate. However, it should be emphasized that the continuation of data collection would permit to obtain results closer to the reality and a better evaluation of the variables. Moreover, the investigation of other factors would be beneficial, since the parameters studied just explain a small variation's amount and so further research is needed.

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